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# Interregional Interaction and Dilmun Power in the Bronze Age: A Characterization Study of Ceramics from Bronze Age Sites in Kuwait

Hasan Ashkanani

*University of South Florida*, [hasan@mail.usf.edu](mailto:hasan@mail.usf.edu)

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Interregional Interaction and Dilmun Power in the Bronze Age: A Characterization Study of  
Ceramics from Bronze Age Sites in Kuwait

by

Hasan J. Ashkanani

A dissertation submitted in partial fulfillment  
of the requirements for the degree of  
Doctor of Philosophy  
Department of Anthropology  
College of Arts and Sciences  
University of South Florida

Major Professor: Robert H. Tykot, Ph.D.  
Thomas J. Pluckhahn, Ph.D.  
E. Christian Wells, Ph.D.  
Jonathan M. Kenoyer, Ph.D.  
Jeffrey Ryan, Ph.D.

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## **DEDICATION**

I dedicate my dissertation work to the awaited savior, Imam Mohammad Ibn Al-Hasan, who appreciates knowledge and rejects all forms of ignorance. A special appreciation goes to my parents and my beloved wife who supported me throughout this process. They have been my best motivators to be a successful person. I also dedicate this dissertation to my siblings, Ashkanani family, and friends who have never left my side and their words of encouragement were what helped me persevere during the hard times of this journey. They have also supported me through obtaining book sources from the Arabian Gulf countries and Europe. I will always appreciate all my American friends for helping me develop my skills, especially Prof. Frank Poirier, Dr. Allison Muhammad, Sean Norman and David Rafael, for their time and infinite support. Finally, I dedicate this work to my elder brother, Mohammad, whose death led me to pursue an academic career and have a significant position and footprint in developing Kuwait history and archaeology.

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## TABLE OF CONTENTS

List of Tables .....	iv
List of Figures .....	v
Abstract .....	x
Chapter One: Introduction .....	1
1.1 Thesis Overview .....	1
1.2 The Study of Ceramic Production.....	5
1.3 Craft Specialization and Ceramic Production.....	6
1.3.1 Using Lines of Evidence .....	6
1.3.2 Characterization Studies of Ceramics .....	8
1.4 Political Economy Theory and Craft Specialization.....	11
1.4.1 Toward Political Economy Theory for the Emergence of Dilmun.....	17
1.5 Aims of this Study .....	19
1.6 Significance of this Study .....	21
Chapter Two: The Dilmun Colony – Failaka Island Site .....	23
2.1 Dilmun: The Sumerian Eden and Paradise .....	23
2.2 Failaka Island, a Dilmun Colony .....	24
2.2.1 Geographical Location and Land Use History.....	27
2.2.2 Archaeology of Failaka.....	30
2.3 Dilmun Political Economy in The Arabian Gulf .....	33
2.4 Dilmun Barbar Pottery and Craft Specialization .....	40
Chapter Three: Research Background .....	47
3.1 Introduction.....	47
3.1.1 Key of Power and Social Complexity .....	47
3.1.2 Craft Specialization and Social Complexity .....	53
3.1.3 Trade, Exchange and Interaction .....	57
3.1.4 Role of Ceramics with Other Materials .....	61
3.2 Socio-political Organization, Trade and Exchange in Kuwait and the Arabian Gulf .....	62
Chapter Four: Theoretical Background .....	67
4.1 Introduction.....	67
4.2 Socio-cultural Interactions that Undergird Trade and Exchange.....	68
4.3 Exchange and Interaction in the Near East and Adjacent Regions.....	79

4.4 Recent Models Applicable To the Future of the Arabian Gulf Research .....	90
Chapter Five: Methodological Background of Archaeometry in the Near East and the Arabian Gulf .....	93
5.1 Introduction.....	93
5.2 Destructive versus non-Destructive: Strengths and Limitations.....	96
5.3 Archaeometry in the Near East and Adjacent Regions.....	107
Chapter Six: Methodology and Samples.....	111
6.1 Introduction.....	111
6.2 Sampling Strategy and Materials .....	113
6.3 Analytical Method: Portable X-ray Fluorescence (pXRF) .....	127
6.3.1 Sampling Exclusions and Limitations .....	127
6.3.2 Error Testing .....	132
6.3.3 Sample Preparation and Processing Data .....	139
6.3.4 Statistical Analysis of Chemical Data.....	141
6.4 Petrographic Thin Sectioning .....	142
6.4.1 Sample Preparation for Petrographic Thin Sectioning Analyses.....	143
6.4.2 Processing Data for Petrographic Thin Sectioning Analyses .....	145
Chapter Seven: Results – Analytical and Statistical Results of Chemical Data .....	146
7.1 Introduction.....	146
7.2 Statistical Analysis of Chemical Data.....	146
7.2.1 Principal Component Analysis for all Research Collections.....	147
7.2.2 Cluster Analysis of all Research Collection .....	151
7.2.3 Discriminant Function Analysis .....	151
7.2.4 Principal Component Analysis for all Failaka Island Ceramic Sherds.....	156
7.2.5 Cluster Analysis for all Failaka Island Ceramic Sherds .....	157
7.2.6 Discriminant Function Analysis for all Failaka Island Ceramic Sherds.....	159
7.2.7 Principal Component Analysis for Ceramic Sherds of all Kuwait and Bahrain Sites .....	160
7.2.8 Cluster Analysis for Ceramic Sherds of all Kuwait and Bahrain sites .....	164
7.2.9 Discriminant Function Analysis for Ceramic Sherds of all Kuwait and Bahrain sites.....	165
7.2.10 Principal Component Analysis for the Early Second Millennium BC Sherds from Failaka Island.....	167
7.2.11 Cluster Analysis of the Early Second Millennium BC Sherds from Failaka Island.....	171
7.2.12 Discriminant Function Analysis of the Early Second Millennium BC Sherds from Failaka Island.....	172
7.3 Results from Preliminary Experiments.....	174
7.3.1 Preliminary Test Results with pXRF .....	174



7.3.2 Results from Preliminary Experiment with Petrographic Thin Sectioning .....	179
Chapter Eight: Discussion.....	180
8.1 Introduction.....	180
8.2 Ceramic Grouping by pXRF .....	181
8.2.1 pXRF Group A.....	181
8.2.2 pXRF Group B.....	184
8.2.3 pXRF Group C.....	190
8.2.4 Outliers.....	198
8.3 Petrographic thin section results .....	208
8.3.1 Petrographic Analysis of Group A.....	209
8.3.2 Petrographic Analysis of Group B.....	217
8.3.3 Petrographic Thin Sectioning Outliers.....	219
8.4 The Potential Provenance of Bronze Age Pottery .....	222
8.5 Conclusion .....	231
Chapter Nine: Conclusion.....	239
9.1 Introduction.....	239
9.2 Discussion .....	241
9.3 The Future.....	245
References.....	249
Appendix A: A List of Abbreviations Used in Dissertation .....	277
Appendix B: List of Elemental Compositions (As Determined by pXRF) of the Analyzed 304 Samples .....	278
Appendix C: A Basic Petrographic Analysis of Cermaics from Kuwait.....	287
Appendix D: Permissions .....	306

## LIST OF TABLES

Table 6.1 Summary of all sample materials from Kuwait, Bahrain, KSA, Iran and Pakistan....	115
Table 6.2 Concentration of ICP-MS and pXRF for 13 selected ceramic samples .....	134
Table 6.3 Pearson correlation between ICP-MS and pXRF .....	136
Table 6.4 A Summary of Sample Materials of Petrographic Thin Section Analysis .....	144
Table 7.1 Component matrix of each variable loading .....	150
Table 7.2 Loading of each variable into each discriminant function.....	154
Table 7.3 Summary of sample materials of all Failaka Island sites.....	157
Table 7.4 Component matrix of each variable loading .....	157
Table 7.5 Loading of each variable into each discriminant function.....	161
Table 7.6 Summary of all materials from Kuwait and Bahrain.....	163
Table 7.7 Component matrix of each variable loading .....	163
Table 7.8 Loading of each variable into each discriminant function.....	167
Table 7.9 Summary of sample materials of early 2nd millennium Kuwait and Bahrain.....	169
Table 7.10 Component matrix of each variable loading .....	170
Table 7.11 Loading of each variable into each discriminant function.....	173
Table 7.12 pXRF data summary for three distinct Bronze Age ceramic groups (ppm) .....	178
Table 8.1 Summary of pXRF groups in relation to petrographic groups .....	233

## LIST OF FIGURES

Figure 2.1 Map of the Arabian Gulf and adjacent regions showing the major sites and locations mentioned in this text (drawing by H������ David-Cuny). .....	24
Figure 2.2 Map of Kuwait and the location of Failaka Island as the first stopping point on the mouth of Shatt Al-Arab (drawing by H������ David-Cuny).....	28
Figure 2.3 Map of Failaka Island showing different archaeological sites and the well-known Bronze Age sites in the western portion of the island (F3, F6 and Al-Khidr) (drawing by H������ David-Cuny).....	33
Figure 2.4 Chain-ridge pottery of City 1 at Qala'at in Bahrain (H������ 1994:76).....	41
Figure 2.5 Red-ridged jars as a characteristic of the Dilmun assemblage during Barbar II or City II (Moon 2005:280-81). .....	42
Figure 2.6 Development of various types of Failaka pottery in Period, type 1B (a), and Period 2, type 32 (b) and type 14A (c) in the early second millennium BC (H������ 1987). .....	43
Figure 2.7 The four dominant fabric types (A, B, C, D-ware) of Dilmun pottery found in Bahrain and Failaka (photo by Hasan Ashkanani). .....	43
Figure 2.8 Sample no. 13609 as A-ware type of Barbar red-ridged pottery showing lime particles in the outer and inner surfaces. Notice artificial white lines on the edge (left) showing thin flakes of lamination (photo by Hasan Ashkanani).....	44
Figure 2.9 Sample no. 13628 as Barbar A-ware type of grey outer and red inner surfaces. Notice white dots on the edge (left) showing two zones (photo by Hasan Ashkanani). .....	45
Figure 2.10 Two Mesopotamian fabric types for wheel-made vessels, yellowish pink E-ware and pale greenish straw impression G-ware (photo by Hasan Ashkanani).....	46
Figure 6.1. Chronological Chart of the late third-second millennium BC in Failaka Island and Bahrain sites (H������ 2012). .....	117
Figure 6.2 Map of southwestern Mesopotamian, the upper Arabian Gulf and southwestern Iran showing Deh Luran and Susiana plains in Khuzestan, Iran. ....	121

Figure 6.3 Map of settlements in Harappa showing Mound E and AB. Note the kiln area within Mound E (Dales and Kenoyer 1991). .....	125
Figure 6.4 Plan of kiln area in Mound E, Harappa (Dales and Kenoyer 1991). Ceramic sherds were taken from outside the kiln and inside the kiln (circular wall). .....	126
Figure 6.5 Selected spots (A, B & C) within each ceramic sherd for pXRF avoiding non-flat area. The slipped outer was selected to examine its homogeneity with the inner surface (Photo by Hasan Ashkanani). .....	130
Figure 6.6 Biplot of Rb vs. Y (A) for ceramic data collected using pXRF for multiple shoots within each sample. The Rb vs. Z (B) confirms the outer surface of 14232 due to paint and 14243 due to darker spot as an indicator of cooking process. ....	131
Figure 6.7 Selected elemental plots for three Dilmun ceramic samples from Kuwait. Open diamonds are samples analyzed using ICP-MS and filled diamonds are ceramic samples analyzed through multiple shoots by pXRF (Stremtan et al. 2014). .....	134
Figure 6.8 Selected elemental plots for 10 ceramic samples. Open squares are samples analyzed using pXRF and filled squares are samples analyzed by ICP-MS. ....	135
Figure 6.9 Biplot derived from PCA of covariance matrix of 13 pottery samples measured by ICP-MS and pXRF. ....	137
Figure 6.10 Elemental plots showing the best separation of samples analyzed by ICP-MS and pXRF using elements Rb, Sr, Th, and Nb. ....	139
Figure 6.11 pXRF at the Archaeological Science Laboratory, University of South Florida, Tampa. The lightweight of pXRF (2 kg/ 4.49 lbs.) allows users to conduct the analysis in the laboratory or in situ (photo by Hasan Ashkanani). ....	141
Figure 7.1 A biplot of Rb/Nb vs. Sr/Nb discriminating between and within sites and separating the Indus Valley collection (pink square) from Dilmun (pink circle and blue triangle) and Mesopotamian and Iranian sherds (green and red). ....	148
Figure 7.2 A biplot of Rb and Sr showing the best separation of groups/samples between Dilmun sherds (A) and Mesopotamian-Iranian (B). Some samples from Dilmun sites overlap with the Mesopotamian group. ....	149
Figure 7.3 A biplot of Y/Rb vs. Ba/Rb showing the Al-Khidr sherds (blue circle) within the Dilmun group and some outliers overlapping with the Mesopotamian House collection (green diamond). ....	149

Figure 7.4 Biplot derived from PCA of 304 sherd and clay samples measured by pXRF, showing variation within Failaka Island and Bahrain sites. At least two distinct groups of ceramics (Harappa vs. Dilmun) are noticed and potential outliers from Al-Khidr, F3, and F6 in Kuwait and the Deh Luran region. ....	150
Figure 7.5 Plot using PCA scores and presuming 5 clusters showing at least three distinct groups in the sample collections .....	152
Figure 7.6 Canonical discriminant functions 1 and 2 showing at least two main distinct groups and a large number of ungrouped samples.....	153
Figure 7.7 Biplot of discriminant scores on discriminant function 1 and 4 showing a mixed pattern of specimens from Kuwait and Bahrain sites, along with a well-separated group of the Indus Valley. 78.3% correctly classified. Ellipses are made artificially.....	154
Figure 7.8 Biplot derived from PCA of 189 samples measured by pXRF, showing variation between Failaka Island sites. Ellipses are made artificially. ....	158
Figure 7.9 Plot using PCA scores and presuming 4 clusters showing at least two distinct groups with a few outliers.....	158
Figure 7.10 Biplot based on discriminant functions showing at least two (centroid 1,2 vs. 4). Ellipses are made artificially. ....	161
Figure 7.11 Biplot of DF 1 and 2 showing a mixed pattern of Dilmun sherds (group A), along with other two groups (B and C). 71% correctly classified. Ellipses are made artificially.....	162
Figure 7.12 Biplot derived from PCA of 224 samples. Note the match among Dilmun pottery from Kuwait and Bahrain and a few outliers from Al-Khidr and F3. Ellipses are made artificially. ....	164
Figure 7.13 Plot using PCA scores and presuming 4 clusters showing two groups and possible other small groups. Ellipses are made artificially.....	165
Figure 7.14 Biplot based on discriminant function showing two group (centroid 1, 2 vs. 3). ....	167
Figure 7.15 Biplot of DF 1 and 2 showing a mixed pattern of Dilmun sherds (group A), along with the Mesopotamian House (group B). Note a few potsherds from F3 clustered alone (group C). 72% correctly classified. Ellipses are made artificially. ....	168
Figure 7.16 Biplot derived from PCA of 75 samples. Note the Barbar Temple II sherds overlap with the Mesopotamian House collection and outliers from F6. Ellipses are made artificially. ....	170

Figure 7.17 Biplot of cluster analysis using PCA scores and presuming 3 clusters, showing two distinct groups and a few outliers. Ellipses are made artificially.....	171
Figure 7.18 Biplot based on canonical discriminant functions showing two distinct groups and a potential third one (after Ashkanani and Tykot 2013) .....	173
Figure 7.19 Biplot of DF 1 and 3 showing a mixed pattern of Dilmun specimens from Failaka and Bahrain sites (Group A), along with the Mesopotamian House cluster (Group B). Note that a few sherds from the Palace were combined together (Group C). Ellipses are made artificially.....	174
Figure 7.20 Ceramic sherds from Susiana Plain and Deh Luran (in the top) as their colors range from greenish to pale gray and N. Susiana (in the bottom) as reddish to pale brown. ....	177
Figure 7.21 A collection of clay samples analyzed by pXRF. Clay samples A and B are the only samples clustered with the Dilmun group while the others are scattered. ....	178
Figure 8.1 Group B consisting of Mesopotamian tradition sherds, from six archaeological sites, as their colors range from pale greenish, brownish, to pale gray. ....	188
Figure 8.2 All nine samples clustered with group C resemble the Mesopotamian shape. Note that the Qala'at sherd (no. 13693) is more greenish. ....	192
Figure 8.3 Samples as outliers from F6, F3, and Al-Khidr in Kuwait and N. Susiana in Iran – scattered outside the three main pXRF groups.....	199
Figure 8.4 Thin section micrograph of the Group A.1. All samples in this group belong to Barbar tradition that is comprised of iron-rich silty and micaceous clay and sand temper. All images taken in plain polarized light. ....	210
Figure 8.5 Thin section micrographs of Group A.2 samples. Limestone inclusion (red circle) in sample 13620 and darker edge in both sherds are noticed. All images taken in plain polarized light. ....	211
Figure 8.6 Thin section micrographs of Group A.3 samples showing a variation of clay types used for Barbar pottery. Images taken in plane polarized light (nos. 13622, 14231, 14235, 13679) and in crossed polars (nos. 13634, 13662, 13681). ....	213
Figure 8.7 Thin section micrographs of zonation in Barbar red-ridge jars. The outer (o) margin is darker than the inner (I) of the core due to rapid firing and cooling. Top right (no. 13664) and left (no. 13701), and bottom right (no. 13699) and left (no. 13694). ....	218
Figure 8.8 Thin section micrographs of Group B samples that have a fine grain texture and calcareous clay. All images taken in plane polarized light. ....	219

Figure 8.9 Thin section micrographs of Outlier samples from Failaka and Bahrain sites.	
All images taken in plane polarized light. ....	221

## **ABSTRACT**

The Dilmun civilization appeared in the Mesopotamian sources as a land of Eden and a supplier of ivory, copper, pearls and dates whose boats reached Ur ports. After the collapse of the Akkadian power in the second half of the third millennium BC, Dilmun underwent some notable changes in different aspects of life. The presence of planned residential settlements with notable architectural features and numerous burial complexes and 'Royal Mounds' in Bahrain marked great economic growth and socio-political development in the early second millennium BC, suggesting the emergence of a stratified social hierarchy.

Furthermore, these changes suggest that a centralized administration existed that controlled this growth through various means. Thus, this inquiry seeks to explore whether the distribution of Barbar wares was one of the mechanisms used to control the economic growth of the Dilmun trade network. Also, this study seeks to explore whether a connection between the presence of non-local wares and far-distance staples in elite contexts on Failaka Island can be used to infer the pronouncement of status, power, and prestige.

A non-destructive portable X-ray fluorescence (pXRF) spectrometer was utilized to examine the chemical composition of 304 ceramic sherds and clay samples along with petrographic thin section analysis, as a complementary tool to investigate the mineralogical composition of Dilmun wares and non-local pottery of the first third of the second millennium BC. Based on seven trace elements (Rb, Ba, Sr, Nb, Y, Z, and Th) obtained from pXRF, the chemical composition of Dilmun pottery was homogenous and was apparently made from a



single source and then possibly produced at a centralized location. However, petrographic thin section results showed that Dilmun pottery could be subgrouped based on the clay and temper used as well as the ancient production technique (e.g. firing temperature). The petrographic analysis supported the pXRF sorting of samples into groups, differentiating between Dilmun and Mesopotamian wares and confirming the non-local wares as outliers. The results suggest that Barbar wares were preferred at Dilmun sites while non-local materials were controlled and their presence minimized. While specific craft recipes and standardization of Barbar wares could not be established, the preference for raw materials from Bahrain proper could.

## **CHAPTER ONE: INTRODUCTION**

### **1.1 Thesis Overview**

The Dilmun culture underwent some notable changes during the Bronze Age. The oldest Bronze Age sites on Failaka Island coincide with the Barbar (City) II period in Bahrain (ca. 2050-1750 BC.). The astonishing expansion during the Barbar II period has been noted in all aspects of life. Bahrain replaced the Eastern Province as the center of the Dilmun polity and transformed into an active trade port, after an expansion in settlement pattern. Qala'at (Bahrain) became a small, urbanized trading port and a fortified capital with a small surrounding wall extending over more than 30 hectares.

By the end of the third millennium BC, planned residential settlements with notable architectural features (i.e. temples, municipal buildings, etc.) marked great economic growth and socio-political development. Furthermore, numerous burial complexes and 'Royal Mounds' in Bahrain have been dated to the early second millennium BC, suggesting the emergence of a stratified social hierarchy. The latter suggests that a centralized administration existed that controlled this growth through various means. Thus, this inquiry seeks to explore whether the distribution of Barbar wares was one of the mechanisms used to control the economic growth of the Dilmun trade network. Also, this study seeks to explore whether a connection between the presence of non-local wares and far-distance staples in elite contexts on Failaka Island can be used to infer the pronouncement of status, power, and prestige.

This inquiry examines the production of pottery in the Dilmun territory (i.e. Failaka Island, Kuwait, and Bahrain) during the Bronze Age. Furthermore, this study investigates the provenance of Dilmun ceramic production as well as non-local wares that were exchanged in Dilmun territories. Specifically, it examines the standardization of chemical composition of ceramic sherds from Dilmun sites on Failaka Island and Bahrain using a non-destructive portable X-ray fluorescence spectrometer (pXRF) and petrographic thin section analysis. The petrographic thin section analysis was carried out as a complementary tool to investigate the mineralogical composition of Dilmun wares and far-distance pottery of the first third of the second millennium BC.

The aims of this study included the following: (1) to explore the development of pottery production; (2) to determine if standardized production recipes were used for Barbar wares; (3) to link provenance sources to production sites, namely to see if a specific site had access to non-local pottery; and (4) to determine if the standardization of provenance sources and production techniques of Barbar wares could be used to suggest Dilmun's elites having had socio-political authority in the region.

To explore these aims, chemical and mineralogical studies were undertaken to find compositional groups and the results were interpreted to explore any association between each group, cultural phase, and any spatial relationship. pXRF analysis was carried out on 304 ceramic and clay samples from Dilmun sites in Kuwait and Bahrain and non-local potsherds from Mesopotamia, Iran and the Indus Valley, each serving as a reference group of their provenance. Also, 25 samples were tested using petrographic thin section analysis to test the reliability of the pXRF results and to identify a scale of standardization.

Three main chemical groups were identified using the pXRF compositional data: Group A, Group B, and Group C. Also, another group of *outliers* from different sites was observed. Interestingly, there was no correlation between each chemical group and a specific site. Group A represents all Dilmun potsherds from Kuwait and Bahrain and from all cultural phases. Group B represents the Ur III potsherds from the Mesopotamian House on Failaka and the assumed Mesopotamian tradition samples from Dilmun sites. Group C represents only the ceramic potsherds from Failaka that date to the Kassite period (ca. 1550 BC). The outlier group represents various potsherds from different sites on Failaka Island. There was no correlation observed between each chemical group and each archaeological site and chronological phase. Based on the seven trace elements (Rb, Ba, Sr, Nb, Y, Z, and Th) obtained from pXRF, the chemical composition of Dilmun pottery is homogenous and were apparently made from a single source and then possibly produced at a centralized location. However, petrographic thin section results showed that Dilmun pottery could be subgrouped based on the clay and temper used as well as the ancient technique (e.g. firing temperature). The petrographic analysis supported the pXRF sorting of samples into groups, differentiating between Dilmun and Mesopotamian wares and confirming the non-local wares as outliers.

Perhaps indirectly, the emerging Dilmun (Bahrain) authority and administration controlled the distribution of far-distance materials by the beginning of the second millennium. Occupying Failaka Island strengthened their northern border and allowed them to break the direct connection between southeast Arabia and farther regions (i.e. Magan and the Indus Valley and Mesopotamia). The multiple clay sources and non-standardized raw materials for Dilmun pottery in the early second millennium points to pottery production that was not centralized even though the ridge style and the appearance of certain ware types (i.e. A-, B-, and C-ware) was

observed in the beginning of the Barbar culture. The variation of clay constituents amongst Dilmun wares suggests potters were able to select their own preferred mediums for production, but chose popular styles for the final shapes of their vessels.

The non-standardized Barbar pottery recipes suggest a professional potter class was involved in the mass production of the wares, but was not attached to the centralized administration (centralized specialist). In the case of Dilmun, the socio-political and economic development could not be inferred by the raw materials and firing technique, as was witnessed in Uruk ceramics in ancient Mesopotamia (ca. 5500-3100). The absence of physical workshops and production debris within the Dilmun territory would preclude having indirect evidence about the level of craft activity. The practice of control and power on Failaka Island seemed limited to the acquisition of non-local materials unlike the administration of Bahrain in which large mounds, city wall and standard weights were pronounced.

Despite the obvious evidence of socio-political complexity, the participation of Dilmun in the interregional trade network seemed centered upon controlling the Gulf route. Dilmun exercised control over the flow of materials during the early second millennium and the distribution of its own Barbar pottery to other Dilmun trading points (Failaka) or trading partners (Oman). The increased presence of stone buildings, temples, settlements, and Dilmun materials can be viewed as due to increased authority and social stratification. However, inferring centralized Barbar pottery production through the standardization of Barbar pottery was not possible.

## 1.2 The Study of Ceramic Production

The role of pottery in theoretical interpretations is important and complicated. Traditionally, some scholars attributed culture contact and exchange to the presence of any foreign ceramics on a given archaeological site, while others proposed that changes in the ceramic typology are indicative of socio-cultural shifts as well as technological innovation (Renfrew and Bahn 2000). From pottery, archaeologists have derived cultural identity (e.g. Edens 1994), implied shifts in power (e.g. Shaw 2000), and discussed ideological notions of power (e.g. Hodder 1982, 1992).

Not only is the distribution of pottery significant, but the production of pottery as well. *Production studies* include characterizing the materials, exploring artisanship, and socio-cultural values (Renfrew and Bahn 2000:373-377). Characterizing pottery requires the archaeologist to identify raw materials, identify probable sources of those raw materials, and link this information to the distribution patterns for the pottery. Exploring artisanship includes the study of *social organization* (i.e. labor organization, apprenticeship, gender roles, etc.), *style repertoire* (i.e. expressions of ideology, gender, artisans' signature, material choice, etc.), and cultural preferences (i.e. popularity, notions of value, rate of exchange, etc.) (Hodder 1982, 1992; Renfrew and Bahn 2000).

Archaeologists can tie socio-cultural values of pottery to distribution patterns. Furthermore, the value producers placed on items as opposed to those that consumed the pottery internally and externally is of interest. For example, Chinese porcelain was valued as a prestigious item by many adjacent cultures, nomads to the northwest and even farther west by Europeans, unbeknownst to the Chinese (Mudge 1981). According to Mudge (1981), the Chinese were not prepared to produce their prestige-based porcelain for the growing, large-scale foreign

demand that carried porcelain all the way to North America. Also, Mudge (1981) wrote that ‘the art’ of production was in the hands of certain lineages of artisans and was not a skill set that the average citizen possessed. The study of pottery has many nuances that the archaeologist has to connect to other material culture and human behavior.

The study of pottery distribution and consumption patterns can be a daunting task. Archaeological theories and their assumptions make it difficult to rely solely upon ceramics as a line of evidence for exchange and interaction. Various concepts have contributed to our understanding about exchange and interaction just based on ceramic studies, such as emulation, colonial, and diasporic communities. The presence of other archaeological evidence (e.g. architecture, jade, obsidian, metal tools, glass, beads, stamps) can contribute more to exchange and interaction studies. Stein’s work (1999, 2002) has shown that the analyses of ceramics needs to be combined with other evidence, such as architectural features and seals, to contextualize interaction between Mesopotamian Uruk and Anatolian cities during the Chalcolithic period.

### **1.3 Craft Specialization and Ceramic Production**

#### **1.3.1 Using Lines of Evidence**

Archaeologists suggest two types of evidence to detect the production unit and scale of specialization, direct and indirect. Evans (1978:115) has suggested that direct evidence is that which is related to finding the context of production, such as workshops, storage facilities, and toolkits. The presence of raw materials, wasters, kilns, and/or finished ceramic products can be a direct indicator of the craft location and activity. However, the quantity of ceramics in one location does not reflect the workshop or craft activity. For instance, the high quantity of lithic micro drills at the Mississippian Cahokia site is not related to the drill production, but it is an

area in which shell beads were made using this specialized tool (Yerkes 1983:500). Sinopoli (1998) has discussed the difficulty in finding direct evidence of ceramic production in southern India. She wrote about the simplicity of firing facilities and low temperature technique used in ceramic production. For instance, because the potters at the Vijayanagara site used low temperatures, wasters were absent and they recycled the ash for field fertilizer (Sinopoli 1998:163).

Evans (1978:115) has suggested that the distribution of craft products is an indirect line of evidence of production. The manufacturing technology and degree of standardization have been used to examine the degree of production (Santley et al. 1986:111). The quantity of standardized items has also been used to discuss the proficiency and efficiency in manufacture (Costin 1991:32). Furthermore, the similarity among products is another aspect of the standardization of the craft. The uniformity of pottery refers to how the potter produced the wares and the internal cultural forces that impact production (Blackman et al. 1993). The similarity in materials used and techniques performed may make wares appear to be uniform. Thus, the finished products appear standardized and the work of specialists as opposed to in relation to non-professionals (Rice 1991:268). The standardization of products can be linked to the experience and skill of the potters or to the production technology (Arnold 1999; Longacre 1999).

In general, the intensity of uniform products reflect a high input of skills and experience of the producers and in some case the value and uniqueness of the object. Underhill (2003) has investigated the degree of specialization and the intensity (i.e. part-time and full-time) of production to examine the degree of standardization as a predictor of intensity in Guizhou. She concluded that part-time potters could make even standardized pottery from China. Based on the ethnographic study, Underhill showed that the little variation among Guizhou pottery reflects



consumer demand and probably market preference. Therefore, morphological uniformity should be considered alongside other factors to explore craft specialization which is not necessary mean that artifacts are standardized. Feinman et al. (1992:240-41) wrote that nested vessels in Oaxaca could be easily fired and transported and that the uniformity was a result of consumer demands and other considerations). There are many factors that should be considered when trying to determine the nature of ceramic production. The lack of direct evidence in Dilmun is one of the limitations in understanding the ceramic production workshop and specialization scale. No pottery kiln has been found on Failaka Island or at Qala'at in Bahrain, nor have any toolkits, ash, or wasters been uncovered at any site (Højlund 1987, 1994). Therefore, indirect evidence may be the avenue by which to explore specialization and production system.

### **1.3.2 Characterization Studies of Ceramics**

To overcome the absence of ethnographic and ethno-archaeological data, compositional studies have been carried out to determine the scale of craft specialization and production organization. The chemical and mineralogical composition of pottery clay and temper materials can be used to explore the scale of standardization. Stein (1999) used instrumental neutron activation analysis (INAA) to analyze ceramic samples from high-ranking individuals' graves in order to determine craft specialization in ancient Mesopotamia. The results indicated artisans used multiple clay and material sources. Also, he concluded that the high variation among pottery from Susa supports the production by independent and non-specialized potters in ancient Mesopotamia (ca. 5500-3100 BC), as opposed to less variation that would have suggested centralized and attached specialists that are controlled by elites and an administrative authority (Stein 1996:29). Feinman et al. (1992) used the petrographic characterization of Oaxaca pottery

paste to investigate the scale of production, commercialization, elites, and political centralization. They concluded that the homogenous clay paste and temper materials suggest the control over raw materials and production efficiency (Feinman et al. 1992:241).

An interesting comparative study of Inka Empire pottery from multiple sites showed a correlation between an increase of Inka power and control over raw materials. D'Altroy and Bishop (1990) showed that the materials' sources became controlled and limited as the Inka political control increased. Furthermore, some material was compositionally associated with pottery strictly for elite consumption. Thus, there was compositional homogeneity and standardization within each production center, but differences between Inka groups according to their status (D'Altroy and Bishop 1990:125).

In the absence of background information on Dilmun ceramic production, a geochemical study has been used to investigate ceramic manufacturing during the Bronze Age. Using characterization (chemical and mineralogical) methodologies can support the study of craft specialization. Also, craft specialization is an avenue to study the level of socio-political complexity of the Dilmun during the second millennium BC.

A characterization study was carried out on materials, dated to ca. the fifth millennium BC, from the Mesopotamian and Susiana plain (Berman 1987). The study investigated the scale of Iranian Susa power in the Great Mesopotamia. The INAA results revealed the homogeneity among black-on-buff Susa Phase pottery, suggesting the administration did sponsor ceramic specialists to make elaborate pots. In general, ceramic production could be used to support the study of the hierarchy in Susa Phase Susiana, if it is considered alongside other evidence, such as seal use and sealing productions.

On the other hand, Ghazel et al. (2008) showed that the sampling strategy of Berman's (1987) study hampered the results as the temporal and spatial variation was evident. With the results, researchers evaluated the hypothesis formulated to explain Susiana ceramic production and centralization in the fourth millennium BC. The results showed that there was compositional diversity between the Susiana Plain sites in the fifth and fourth millennia BC. The results did not support the centralized hypothesis in the Susiana Plain but implied individual workshops and specialists who preferred several clay sources to produce desired attributes in the ceramic paste (Ghazel et al. 2008).

Furthermore, the similarity in the fabric and manufacturing technology between fifth millennium ceramics in Hungary suggests a high level of skill and standardized production that is related to an emergence of social complexity (Kreiter et al. 2009:101-119). The petrographic analysis showed that the Late Neolithic ceramics from three sites shared common fabric and the temper preparation was a single standardized recipe, despite the variation in the shape and size of the vessels.

The study of ceramic characterization (i.e. craft specialization, production, etc.) was used in this research to explore the political and social complexity of the Dilmun. Specifically, the chemical and mineralogical characterization of Barbar ceramics of the Dilmun were investigated as another line of evidence to discuss the Dilmun's emerging presence in the Arabian Gulf during the second millennium BC. The data generated from a characterization study could be juxtaposed alongside other evidence, such as different burial mounds, distribution of non-local goods and items, and differential housing. In addition to the attempt made by archaeologists to study the development of Barbar pottery morphologically, this study is designed to contribute to the discussion about the mechanisms of power shifts.

#### **1.4 Political Economy Theory and Craft Specialization**

The development of socio-political power in Dilmun has been characterized by the presence of mound burials, Dilmun stamp seals, Barbar ridged ware, and temple complexes as well as trading ports during the Bronze Age. The craft specialization, particularly for pottery production and the control of raw materials and access to non-local materials, is of interest to understand the practice of sociopolitical and economic power within the Dilmun realm.

Political economy theories are more supportive of the types of questions that arise surrounding the emergence of a semi-peripheral polity, like Dilmun. According to Sinopoli (2003:1), political economy is a set of “relations between political structures and systems (including the constitution of political authority) and the economic realms of production, consumption, and exchange.” The branch of ‘control’ theories in which potential elites seek to distinguish themselves from others with prestige items (i.e. exotic, specialized, or rare) seems to support the rise of aspiring semi-peripheral polities that may want to replace a collapsing central polity like that of the Akkadians.

At the center of an elite group seeking to have more influence and have that influence translate into political authority and dominance is craft specialization. Elites are seeking to monopolize prestige items to increase their status and numbers. The display of specialized products attracts others for alliances for marriage and further trade. Control of raw materials, production techniques, and finished products as well as the very lives of the craft specialist (Sinopoli 2003:15) support the aspirations of an emerging elite group. Niziolek (2011:47) wrote that the control of prestige items is completely self-serving for elites. Also, the management of the circulation of finished items can be used as a unit of an emerging elite group and administration. The development of Barbar pottery seemingly occurred parallel to the increase of

Dilmun power and expansion in all aspects of life. The presence of a new centralized institution, elite mounds burials, and monumental structures were an indicator that some change occurred in Dilmun at the beginning of the second millennium BC.

In general, the application of the political economy model assumes there was unequal access to wealth and power (Roseberry 1989:44). Therefore, archaeologists have used the aspect of how elites govern and control resources as a core of studying political complexity (Hirth 1996). In other words, the development of political organization is based on control over sources, exchange, production and labor. Johnson and Earle (1987:13) defined political economy as an extraction of surplus to support finance religious, social and political institutions that are administered by non-food personnel; thus, elites take stewardship over resources to maintain economic, political and social functions.

Claessen and van de Velde (1991) defined the controller of resources as centralized governments that would be involved in resource accumulation, management, and reinvestment. Thus, the growth of monumental structures, buildings, and urban manifestation reflects the growth of a centralized government. The political economy structure is not only based on the control of resources, but also on socio-cultural relationships and the ideological linkages that cement those bonds. It is the multi-faceted nature of relationships and dimensions that characterizes and underlies the structure of political economy (Hirth 1996:220-21).

Archaeologists have focused on the dimension of the political economy model that involves the production and exchange relationship. This approach followed the classic Marxist bent regarding the role of elites controlling production in the formation of political evolution (Hirth 1996:207). The control of production and resources is linked to the scale of the interaction and exchange system. Archaeologists who follow the substantive economic approach (e.g. K.

Polanyi's 1957a, b, c and Bohannon and Dalton's 1962) have focused more on the interaction and exchange in the emergence of centralized political authority, either as long-distance or as a large-scale world-system interaction (Chase-Dunn and Hall 1993; Kohl 1987a; Renfrew and Cherry 1986). Near Eastern archaeologists have used this dimension to explain the presence of Mesopotamian artifacts from Uruk colony sites in Syria and Anatolia as administrative control on trade and exchange by Mesopotamian administration (Algaze 2001). The exchange and production relationship needs to be studied in a way to consider all the participants within the trade network; thus, elites from amongst all the participating polities could be seeking to accumulate resources and exercise control over their community and a wider network (Hirth 1996:207).

The second aspect of the political economy structural model is the food and commodity relationships. The importance of food production, storage, and surplus are also very important to political growth, just as are the control of resources and nonperishable commodities (Hirth 1996: 208). Childe (1950) argued that the production of a food surplus and technological progress is very important in the evolution of social complexity; the surplus is necessary to support social elites, craft specialists, priests, military personnel, and government bureaucrats (D'Altroy and Earle 1985; Hirth 1996). Therefore, controlling the staple finance, such as grains, clothing, and livestock is crucial as much as the wealth finance. The centralized administration would control staples and their movement amongst commoners as well as labor mobilization (D'Altroy and Earle 1985:188).

The aim of this system is to attach households and personnel, on a part-time basis, to the state that would in turn supply the household units that lacked subsistence goods. The main disadvantage of staple finance is the cost of bulk storage and transportation in which the goods

are large in relation to their value (D'Altroy and Earle 1985:188). Population growth and pressure could be a motivator on the authority to increase the quantity of food resource (Hirth 1996:208). In the wealth finance, the state or elites would control certain craft goods, such as luxury items and their circulation. Thus, they expand their regional and political networks as well as define their social identity as managers.

Furthermore, they also attempt to maintain their social identity by attaching the craft specialists to themselves (D'Altroy and Earle 1985:188). The goal of such a system is to exert more administrative control over craft specialization and the mobility of both raw materials and finished luxurious items. The disadvantage of such a system is the restricted value of commodities and the need for their value to be converted to subsistence or utilitarian support for non-agricultural personnel (D'Altroy and Earle 1985:188).

The third dimension of understanding the evolution of political economy is that this structure is a product of ideological forces. This approach is in the middle ground between materialist and ideational perspectives. Hirth (1996) argued that political power is drawn through the society's religious and social structure; thus, ideology is a motivator of resource mobilization. It provides the structure and justification to operate under political bureaucracies (Hirth 1996:209).

Among all these perspectives, this research focuses on the scale of production strategy and exchange-oriented strategy as appropriate models to characterize the political economy of Dilmun in the Bronze Age. Production strategy is concerned with the control of surplus, wealth and staples, and craft activity (Hirth 1996) that is the parameter to be tested for this research. The exchange-oriented strategy focuses on the mobilization and exchange of resources. The scale of exchange and interregional interaction is another parameter.

The control of craft specialization is linked to the political economy structure because it is an aspect of elites' control over production. Production refers to the effort of transformation of raw materials into usable products and specialization is the way to organize this production (Costin 1991:3). Craft specialization is a degree to which individuals involved in making certain items function either as an independent or as an official; also, it is when artisans devote part of their time to make products (Evans 1978:115). Sinopoli (2003:1) views specialization as the relationship between more or less skilled producers, consumers, and products.

In order to understand the political economy, archaeologists have focused on the 'type' of craft specialization that addresses the scale of production. Brumfiel and Earle (1987) elaborated on the form of craft specialization as production by independent and attached specialists. The independent specialist is one who could produce goods and service for an unspecified demand that varies according to political, economic, and social conditions (Brumfiel and Earle 1987:5). The attached specialist is usually one that produces goods and service to meet the need of his patron or elite; thus, he is usually involved in the manufacture of luxury items and the provision of the institution (Brumfiel and Earle 1987:5). This specialist may be a member of the elite and makes particular goods for enhancing their collective power and social status more than based on a purely economic purpose (Ames 1995). Underhill (1996:136) pointed to labor intensive products that require elite patronage, such as finely made ceramics and metals, as an indication of an attached specialist. Elite patronage of specialists is another pronouncement of wealth and power.

Presumably, this attached specialist would be required to employ some standardized technologies that are associated with the elites. Examples include Harappan drilling beads with a standardized drill, finely carved steatite seals, glassy faience and stoneware bangles as well as



the technology of writing (Kenoyer 2008a, 2008b:726). On the other hand, the independent specialist is guided by the principle of efficiency and security in which he may produce subsistence or luxury items where the gain in efficiency is great (Brumfiel and Earle 1987:5). Like Brumfiel and Earle, Sinopoli (1988) views the scale of elite control as an indicator of the type of specialization. She outlined three types of specialization, such as: “administered” specialization as a direct control of administration over attached specialists; “centralized” as a production specialized in distinct spatial area but no direct evidence of elite control; and finally “non-centralized” as a product not made or controlled by administration and elites. Costin (1991) pointed out that the products of attached specialists can help to differentiate between institutionalized versus non institutionalized specialized products.

In addition to defining craft specialization, archaeologists have attempted to identify the types of organization of production. Van der Leeuw (1977) suggested six types of production, which were based on the increase of intensity: 1) household production is where the product is consumed within the household; 2) individual industry involves the utilization of local materials by a craft specialist; 3) household industry is where products are made in the household but for community consumption; 4) workshop industry refers to year-round craft production but outside of the household; 5) village industry is when workshops create products for consumption beyond their own village; and finally 6) large-scale industry is when different highly specialized people are involved in large investment in material, labor and facilities. Hirth (2006) was able to differentiate, based on chipped-stone industries in highland central Mexico at EpiClassic (ca. 650-900 AD), between household production and domestic workshop in one hand and the marketplace production in the other. The household manufacturing of obsidian tools relied on labor of family members while the marketplace production relied on different families and

perhaps artisans from outside the community (Hirth 2006). However, Feinman (1999:95-96) has shown that there is a challenge to demonstrate the type of organization of production and product intensity. The household of Ejutla Valley in the southern Oaxaca during the Classic period (ca. 200-800 AD) engaged in the high intensity production of marine-shell ornaments (more than 20,000 pieces) which does not appear to produce them for only community consumption. Thus, the low-intensity and part-time industry does not necessary associate with the household production (Wells 2012). Therefore, some Mesoamerican archaeologists suggested that there are alternative concepts that characterize crafting and manufacturing more useful than the term of ‘intensity’. Hirth (2009) advocates for the ‘intermittent crafting’ or periodic crafting and ‘multicrafting’ which craft production activities is occurred in a single household. Therefore, identifying the form of craft specialization and type of production organization could reveal the nature of how specialization is connected to centralized administration. The main question generated by archaeologists is how to identify the production unit, type, and scale of specialization based on the archaeological data in particular to ceramic production.

#### **1.4.1 Toward Political Economy Theory for the Emergence of Dilmun**

In general, the research inquiry is based on Dilmun’s growing prominence in the Arabian Gulf maritime trade network during the Bronze Age. Despite the extensive and continuous archaeological excavations in the Arabian Gulf, there is still a need for a theoretical framework that can address the nuances of the region’s socio-political complexity. A few attempts have been made to evaluate data and provide insights on the circulation of materials and interregional interaction in the Gulf during the Bronze Age.

In addition to the Central Trade model proposed by Lamberg-Karlovsky (1972), Edens (1987, 1994, 1999) has introduced a modified version of Polanyi's "port-of-trade" for the Late Bronze Age in Bahrain and Qatar. Port-of-trade was Polanyi's concept (1963) that discussed the exchange economy between two independent societies, such as between market and non-market societies that have professional traders. Traders can control interaction by settling in another society for economic purposes. Edens (1987, 1994) used an aspect of this concept to discuss the control of the flow of commodities and cultural identity between Qatar and the Babylonian Kassites during the second half of the second millennium trade. For instance, he argued that the relationship between Mesopotamian Kassites and Qatar was based on port-of-trade exchange. The Kassites had control on purple-dye production, processed from the shellfish *Thais*, for coloring textiles. The Kassites further restricted the route of purple-dyed products from Dilmun to Mesopotamia, whether controlling private activities (sailors) or having institutional dominance. The Kassite pottery, at Khor Ile-Sud in Qatar, was the vehicle for the institutional control of the purple dye industry in the Gulf.

Rouse and Weeks' (2011) work proposed an agent-based model as a new approach for investigating the role of individuals within the internal exchange economy in the Gulf, particularly in the Early Bronze Age of southeast Arabia. This study focused on local production and specialization within the Gulf in order to discuss the generation of inequality and socio-economic change. Socio-economic change was a result of individuals who maintained their wealth (i.e. tools, livestock, goods, etc.) and status based on craft specialization and exchange economy; thus, a hierarchal social order based on affluence. Rouse and Weeks (2011) did not evaluate which materials or products were the most profitable that in turn would motivate individuals to maximize their effort to get access to the raw materials and produce the product.

Practice and agency theories could extend the scale of interaction and overcome the agent-based model. They can combine external factors and individual agency as catalysts for socio-economic change. Practice and agency theories emphasize the roles of individuals in leading social change. Individuals have always been an essential factor in creating and developing a new social class or society from non-egalitarian to ranked societies (Clark and Blake 1993). The actions of individuals in acquiring materials and prestigious goods are considered catalysts for social evolution. Their endeavors socially and culturally cascade in a myriad of ways, transferring ideology, technology, or political structures along with the materials exchanged (Mauss 2000; Renfrew and Bahn 2000). Implicit to this model is a study of the value of materials exchanged as oppose to commodities traded out of necessity.

## **1.5 Aims of this Study**

The growing participation of Dilmun in the Arabian Gulf trade network was parallel to other socio-political and economic developments that occurred in the late third millennium, ca. 2050 BC. The development of stone works, planned settlement patterns, pottery production, temple building, royal burial mounds, and standardized stamp seals accompanied the Dilmun political hegemony in the beginning of the second millennium BC.

The shift in pottery production techniques at Dilmun, from chain style in the pre-Barbar to a well-fired hand and wheel-made in the Barbar Period to a well-fired hand and wheel-made in the Barbar Period, could have been an important factor in the evolution of Dilmun socio-political complexity (chapter two). Højlund (1994a) has characterized pre-Barbar period pottery production at the Qala'at site as exclusively hand-made, with irregularity and unevenness in the rim, nick, and body regions. However, during Barbar Period II in the early second millennium,

use of the wheel technique increased at the Qala'at site in addition to the hand-made pottery. Also, imitations of imported goblets were introduced, implying the acceptance of innovations in Dilmun pottery production (Højlund 1994a). The wheel-turntable pottery has a limited number of styles and a small repertoire of luxury productions, suggesting craft specialization and standardization in production (Højlund 1994b).

During the Barbar Period (2050-1800 BC), the red-ridged ware, a Barbar type, became widespread in Bahrain. Furthermore, this increase coincided with a decrease in Mesopotamian pottery and a disappearance of southeastern (Umm an-Nar) pottery types (Crawford 1998; Højlund 1994a; Larsen 1983). New shapes of pottery were developed in this period and other shapes became much more dominant (Højlund 1987, 1994a). The Barbar Period wares were hand-made red-brownish, and hard-fired, with yellowish slip covering the outer surface. Painted pottery was introduced in this period, both local and imported, particularly the 'Eastern Tradition' wares from Iran and the Indus Valley (Crawford 1998; Højlund 1994a; Larsen 1983).

The Barbar type wares that have been found on Failaka Island, represent a wide range of Barbar ware types, such as shouldered vessels, neck or neckless ridged jars, plates, goblets, bowls, and cooking pots. Furthermore, the Barbar Period II pottery, particularly the IIb phase (ca. 1950 BC), is parallel to the pottery of the Barbar Temple's Period IIb and Failaka pottery, Period 1. The pottery production of this period is consistent with Barbar Period IIa in general with such commonality in wheel-made pottery for the large jars, suggesting an improvement in skills (Højlund 1994b).

This study seeks to build upon previous typological studies and inquiries into trade and exchange to explore the emergence of Dilmun socio-political authority. Using pXRF and

petrographic thin analysis, I explore the provenance of ceramics recovered from Dilmun sites on Failaka Island, Kuwait and Bahrain.

## **1.6 Significance of this Study**

Theoretically, this dissertation addresses the political economy of ancient Dilmun in the second millennium BC and examines the level of socio-political complexity. The standardized appearance of the pottery strongly suggests that Barbar wares were mass-produced by professionals, and had shifted gradually from a household level of pottery production. The shift in ceramic craft production was parallel with increasing socio-political complexity. Therefore, I intend to examine Dilmun ceramics from Failaka Island sites to determine if standardized production recipes (chemical and mineralogical compositions) were used for Barbar wares. I am suggesting that Dilmun elites may have controlled the production and distribution of Barbar wares as a part of their other economic activities that are associated with their emerging socio-political authority.

Also, the centralized administration's officers and elites of Failaka may have been seeking to monopolize prestige items (i.e. non-local pottery, other exotic items, etc.) to increase their status. This provenance study has been able to characterize to some degree the level of involvement of the centralized administration in ceramic production. Control of raw materials, production techniques, and the distribution of finished products, as well as the very lives of the craft specialists (Sinopoli 2003:15) support the aspirations of an emerging centralized authority and elite group.

Specifically, this study employed archaeometric applications, such as portable X-ray fluorescence (pXRF) and petrographic thin section analysis. This study uses these techniques to

group Bronze Age ceramics and possibly fingerprint production centers using Dilmun ceramic sherds from Failaka Island sites and other non-local remnants as geological references.

Characterization studies for Arabian Gulf ceramics can be very useful to determine the provenance of ceramics, ancient technology and raw materials. It is also important to obtain information about what is valuable within the trade network, and interregional interaction in the ancient Persian Gulf. Thus, this study was designed to reinterpret aspects of the interregional ceramic trade network with a combination of techniques.

Although many studies have been conducted on the ancient Arabian Gulf trade network during the Bronze Age, very little attention has been given to Kuwaiti Bronze Age ceramics and ceramic technology. Previous works were descriptive excavation reports and typological studies that reported site information and significant recoveries (Al-Bader 1978; Benediková 2008; Bibby 1969; Calvet and Gachet 1990; Howard-Carter 1972; Højlund 1987; Kjaerum 1983). These studies focused on describing the archaeological materials, such as Dilmun and Sumerian stamp seals and ceramics. Typological studies provided generalizations about cultural affiliation and chronological schematics. Through this characterization study, I intend to contribute data that allows for interpretations that can reach beyond the descriptive nature of typological studies.

## CHAPTER TWO: THE DILMUN COLONY – FAILAKA ISLAND SITE

### 2.1 Dilmun: The Sumerian Eden and Paradise

Dilmun was an early civilization that was located in the contemporary Kingdom of Bahrain. Its inhabitants developed technical skills, formed economic and political units, and expressed themselves in art and cultural materials beginning in the third millennium BC (Potts 1990; Vine 1993:15). By the second millennium BC, Dilmun culture has been clearly identified geographically on Bahrain, Failaka Island (Kuwait) and Tarut on the eastern coast of Saudi Arabia (Crawford 1998; Potts 1990). Strategically, Dilmun was located on the sea route between Mesopotamian, Magan and the Indus Valley. Thus, it developed a strong political, economic, and cultural interaction confirmed by the archaeological record (Figure 2.1).

Significantly, there is Sumerian literature that referred to Dilmun as both a trade center and the region in which the god of fresh water, *Inzak*, was worshipped (Alster 1983:59). Early scholars purported that ancient Dilmun was indeed modern Bahrain based on Old Babylonian cuneiform inscriptions that were recovered from Bahrain. These inscriptions mentioned a servant of the god *Inzak* (Larsen 1983:31). In 1928, some scholars presented additional support to the earlier argument based on additional textual evidence (Larsen 1983:31). They linked the Dilmun with Bahrain based upon an earlier translation of the Sumerian paradise myths, which make a connection between the deities *Enki* and *Ninhursag* with the existence of freshwater springs in Dilmun (Larsen 1983:31). Peter Bruce Cornwall, a young American scholar, addressed the



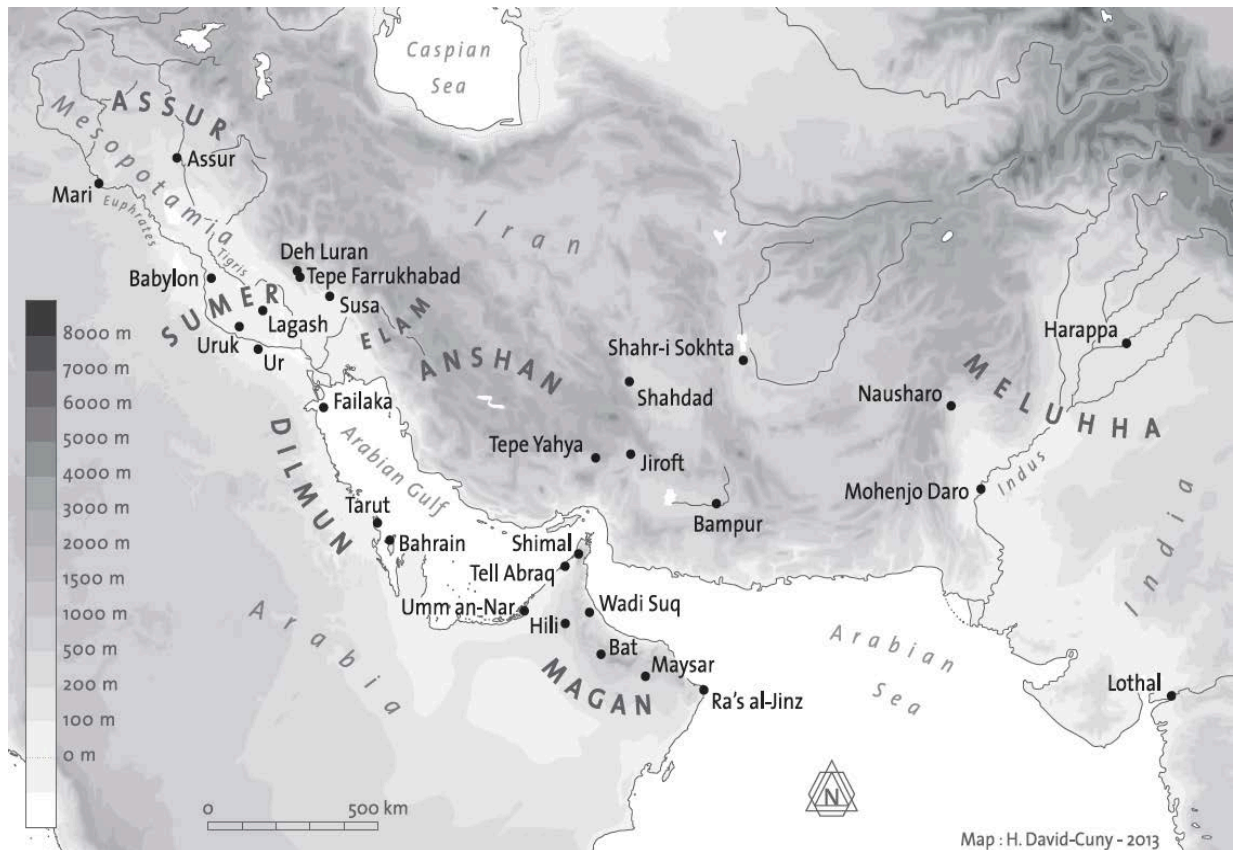


Figure 2.1 Map of the Arabian Gulf and adjacent regions showing the major sites and locations mentioned in this text (drawing by H       David-Cuny).

Dilmun identity issue with his research, carried out in 1940 and 1941. His dissertation was an analysis of textual evidence in Bahrain along with other burial mounds on Bahrain Island from the Bronze Age (Cornwall 1946).

## 2.2 Failaka Island, a Dilmun Colony

In 1937, local people on Failaka Island discovered an irregular, engraved slab of limestone. The translation recorded that some Greek sailors had survived a shipwreck off the coast of Failaka Island. The sailors had offered this writing as a tribute to what they believed was a sacred island, the dwelling place of Poseidon, the sea god (Nourel-Din 1993:14; Salem

2006a:40). In the late 1950s, other slabs with engraved inscriptions were discovered recording the name of the island as Ikaros and a local governor (Bibby 1969:247-248). This led the National Museum of Kuwait to invite a Danish archaeological expedition in 1958 to begin their investigation and conduct excavations on the island. The expedition discovered steatite seals and ceramic artifacts that were traditionally associated with Bahrain. The discovery of architectural features that were filled with pottery, metal objects, and figurines proved that a large and sophisticated community had lived on Failaka (Calvet and Gachet 1990). It was suggested that some of these remnants could be associated traditionally with the Dilmun culture.

The Dilmun culture spread from Bahrain, in the middle of the Arabian Gulf, ca. 2500 BC and some evidence suggests its earliest development began on Tarut Island in the early third millennium (Crawford 1998; Potts 1990). In general, Dilmun refers to a culture that thrived in modern-day Bahrain, the Eastern Province of Arabia, particularly Tarut Island, Saudi Arabia, and Failaka Island, Kuwait. The Sumerians relied on Dilmun agents to transship or move raw materials and products back and forth along local waterways and sea routes from southern Mesopotamian ports to their trading partners as far away as Magan in southeastern Arabia and the Indus Valley. The lack of raw materials in Mesopotamia propelled southern cities to trade with neighbors to acquire metals, wood, shells, ivory, and pearls in exchange for textiles and wool (Weisgerber 1986).

Textual evidence from the Early Dynasty period mentioned cargos of wood, merchants, and boats shipping from Dilmun (Ratnagar 2004). A textual account from King Sargon (ca. 2334 BC) is one of the most cited references by archaeologists and historians describing the nature of ancient trade in the region. That record contained references to the involvement of Dilmun in third millennium trade and its role as one of the smaller entities under the expansion of Akkadian

power. Also, it referred to the other neighbors, besides Dilmun, who participated in the extensive trading connection with Mesopotamia - as he was proud to receive ships from Meluhha, Magan (Oman), and Tilmun (Dilmun) and moored in front of Akkad (Ratnagar 2004; Larsen 1983:33). This record implied that Akkadian control over the Gulf was extensive, leaving little room for smaller polities to have prominence - a curtailing of 'middlemen' such as the Elamites, the Iranians, and the Dilmun during this period. Several texts from the late third millennium BC, Ur III period, revealed that the temple organized the Dilmun/Magan trade. Thus, establishing and maintaining trading routes was a major catalyst for the development of Dilmun culture in the Arabian Gulf coastline during the third and second millennia BC. Centrally located in the Arabian Gulf, Dilmun acted as an entrepôt in this long-distance trade linking two large civilizations - Mesopotamia and Harappa.

After the collapse of Akkad, Dilmun came to dominate the Arabian Gulf through the control of transshipping different commodities. Ur III and Isin-Larsa tablets and texts (dated ca. 2112-1763 BC) testify to the role of Dilmun in the trading activity of merchants and objects going from Dilmun to Ur (Ratnagar 2004; Cleuziou 1986; Zarins 1986). In order to increase its power, Dilmun attempted to expand its territory for political and economic competition by occupying Failaka Island in the early second millennium BC. Many scholars have suggested that, in the second millennium BC, Failaka Island was part of the Dilmun culture (Bibby 1969; Carter 1972; Cleuziou 1986; Højlund 1987; Weisgerber 1986). Failaka Island was part of Dilmun's administrative strategy to expand its borders and secure a refueling station for its seafarers and merchants.

In the beginning of the second millennium BC, Failaka Island was a Dilmun port and the first point in the face of Mesopotamian merchants. The different trading products moved to and

from Ur, Harappa (Indus Valley), and Oman included wood, shells, pearl, precious stones and copper (Cleuziou 1986; Potts 1986; Weisgerber 1986). These items could not be moved without stopping at Dilmun. Failaka Island has architectural features, Bronze Age remnants, and Dilmun materials, which support that it shared institutional aspects with the main Dilmun center (Højlund 1987, 2007, 2012; Kjaerum 1983).

It was the heyday of the Dilmun realm because they were able to strengthen their political influence and their economy by controlling the Arabian Gulf trade network. The presence of the walled city of Qala'at, the growth of the Barbar Temple II (ca. 2025 BC), and the Saar settlement on the mainland of Dilmun (Bahrain) in the late third and early second millennium coincided with the rise of Failaka Island's Dilmun settlements, such as tell F3, F6, and Al-Khidr. Archaeological evidence that supports the latter includes ceramic assemblages, Dilmun stamp seals, architectural details, metal tools, and faunal and floral evidence. Specifically, the Dilmun presence is pronounced by the recoveries of Barbar-tradition pottery and Dilmun seals.

Previous inquiries have established the importance of the island in the flow of commodities, such as copper, chlorite, and other materials, from neighboring countries in the region (Potts 1990; Rao 1986). These inquiries were formulated to explore: (1) the ancient trade networks that connected the polities of Meluhha (Indus Valley), Magan (Oman) and Mesopotamia to Dilmun; and (2) the rise of Failaka Island as a trade depot during historic power shifts at about 2000 BC.

### **2.2.1 Geographical Location and Land Use History**

Failaka Island currently belongs to the State of Kuwait and lies 20 km east of the mainland of Kuwait, and opposite Kuwait Bay (Figure 2.2). Its area is approximately 24 km

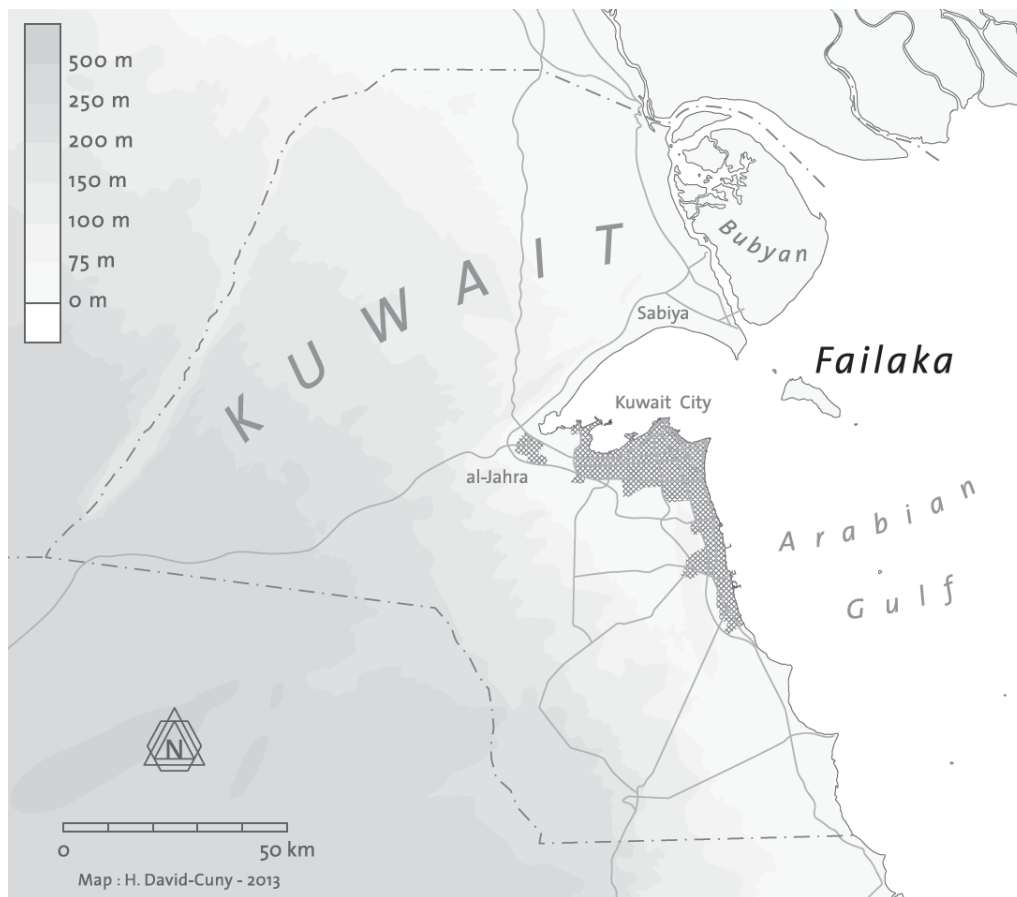


Figure 2.2 Map of Kuwait and the location of Failaka Island as the first stopping point on the mouth of Shatt Al-Arab (drawing by H  l  ne David-Cuny).

which is roughly half the size of Manhattan, New York; its maximum length is 14 km and is roughly 6 km wide (Salem 2006b:9). The island is flat, apart from a small hill 9 m above sea level in the extreme western part.

The island, roughly rectangular in shape, is adjacent to Meskan Island to the northwest, while O'ha Island is adjacent to the southeast. Failaka Island is mostly sandy with some rocky coastlines. The Shbija mound is considered the highest point at about 9 m above sea level (Salem 2006b:9). The entire shoreline of Failaka is considered to be a natural port, where ships used to be protected during storms. The recent excavations by the Slovak expeditions (Benedikov   2010) have shown that the old port of the island was located at the Al-Khidr area in the northern part.

Its position, facing the direction of Al-Basra in Iraq, is considered to be a natural old harbor and a convenient stop on the maritime route along the western coastline of the Arabian Gulf.

Many natural features qualified the island as a choice to accommodate trading expeditions by traders associated with early Middle-Eastern state-level societies. The island contains many water wells along with fertile soil, which supported plantations; this agricultural area constituted 70 percent of the island's geography until the first half of the twentieth century (Salem 2006b:10). Because the island has a natural source of fresh water, its population grew steadily before the invasion of Iraq in 1990. After Iraq was expelled in 1991, the Kuwaiti government resettled the island's inhabitants on the mainland and compensated islanders for their property. Currently, the island is a place for both military exercises and fishing activities. The public may also visit the archaeological sites.

The island has been mentioned in several historical documents and maps. Carsten Neibuhr's map of "Sinus Persicus" in 1765 shows Kuwait as "Koueit" or "Gran", and Failaka as "Feludsje" (Rajab 1999:3). Others have connected the land with Ikaros that is mentioned in Greek sources, such as James Buckingham, the British political agent and explorer. He visited the island in 1816 and was the first to claim that Failaka was called Ikaros in classical Greek writing (Nourel-Din 1993:14; Salem 2006a:100). During the previous century, Colonel H. R. P. Dickson, the British political agent who settled in Kuwait and performed the first archaeological research on the island, described it by focusing on its geographical measurements, population, ruins, vegetation, etc. (Nourel-Din 1993:14; Salem 2006a:107). Thus, finding a Greek inscribed slab in 1937 was the first archaeological effort on the island and was significant in that it inspired scholars to continue their scientific investigation concerning the past civilizations that had settled on the island.

Researchers have disagreed about the name of Failaka itself. Some had said the name was taken from the Latin word “Felix” meaning happy or auspicious. Others thought the name was derived from the Portuguese word “*Felicha*” referring to the pure air of the island (Salem 2006b:12). While these researchers have attributed the island’s name to a romance language, Khalid Salem, a Kuwaiti historian, believed the name was originally taken from the Arabic word “Falaj” which means canal or channel, based on the *falaj* that ran from *Shbeja* to the Al-Khidr area. Salem (2006b:16) explained the Arabic derivation was based on the nature of the island, which has many canals and *Sabkha*, or marshy areas.

### **2.2.2 Archaeology of Failaka**

After the discovery of the Greek inscribed tablet on Failaka Island, the Kuwaiti government invited several expeditions to explore the area. Failaka Island is situated at the entrance of Kuwait Bay and as a point feature in the mouth of the Tigris and Euphrates - Shatt Al-Arab. Actual archaeological research on the island only began in the 1950s with the excavation that was conducted by a Danish archaeological team in 1958. It was under the direction of Professors P.V Glob and T.G. Bibby from the Prehistoric Museum in Aarhus, Denmark. This team had conducted excavations in Bahrain and Qatar from 1953 to 1957 and then in Kuwaiti territory in 1958 (Bibby 1969; Mathiesen 1982). After a survey and trial excavation, full excavations started on Failaka in 1958 and lasted until 1963.

After the Danish expedition discovered architectural remains, stamps and cylinder seals, copper tools, and steatite vessels, the National Museum of Kuwait invited an American expedition to come to Kuwait in 1973. Dr. T.H. Carter, representing Johns Hopkins University, directed this team and expanded the excavation of sites found earlier by the Danish team

(Howard-Carter 1972). In 1976, an Italian expedition conducted brief excavations of several sites exposing ruins dating from the Neo-Babylonian period to Islamic period (Potts 1990:263). In 1982, the Smithsonian of Washington, DC carried out a set of electromagnetic surveys on behalf of the Department of Antiquities in Kuwait. Conversely, the French team initiated an intensive excavation from 1983 to 1985, representing the University of Lyon, the Louvre Museum, and Maison de L'Orient de Lyon, Paris. Under the direction of J. F. Salles, the French mission's excavations were close to the Danish excavations in which the focus was Bronze Age settlements and finds (Salles 1984).

The significance of these early expeditions is that they began to provide a clearer picture of the role of Failaka Island in pre-modern periods. The discoveries by the Danish archaeologists on the island offered sound evidence that Failaka had existed as a 'sacred land' because of its supply of fresh water. It was a flourishing community that resembled, archaeologically, a part of 'the lost nation of Dilmun' that existed between 2000 and 1200 BC. Despite its geographical location proximity to southern Mesopotamia, Failaka Island, according to archaeological records, was not occupied until the beginning of the second millennium BC. The French archaeological expedition, which carried out geo-morphological work on Failaka, has shown that during the mid-third millennium BC the southwestern portion of the island was submerged as a consequence of higher sea levels (Potts 1990:267). However, tests did not indicate how much of the island was submerged.

Failaka's initial occupation around 2000 BC is based on various finds at three sites (F6, F3, and Al-Khidr) on the island that were excavated by Danish, French and Slovak missions (Figure 2.3). A recent excavation by Danish mission has uncovered a structure beneath the second millennium BC layer that dated to Ur III period of the late third millennium BC (Højlund



2012). Some of the oldest as well as major Bronze Age sites are attributed to the Dilmun period. F3 site (F= Failaka) is an archaeological site named by the Danish expedition (Kjaerum 1983:8), and is known as Tell Sa'ad or Dilmun City site. Approximately 2.90 m above sea level, F3 is a residential settlement with documented domestic activities including archaeological evidence of elite structures, skeletons of gazelles and goats, 170 round stamp seals, small stone houses, a temple, and some kilns for unknown purpose (Kjaerum 1983:8; Howard-Carter 1972:207; Rajab 1999:76). The temple was distinguished by the discovery of altars and Sumerian inscriptions on seals. Furthermore, this sacred precinct was apparently dedicated to the god Inzak, chief god during the period of the Dilmun Kingdom from the third millennium BC (Bibby 1969:253-254; Howard-Carter 1972:207).

Approximately 200 m east of F3 and 4.20 m above sea level, the site of F6 is also regarded as a Dilmun site. F6 is the oldest site that is associated with the Dilmun occupation on Failaka. It includes an architectural structure of a temple similar to the second millennium Barbar temples in Bahrain. Ten meters east of the temple is a Bronze Age structure that is thought to be a palace based on its size and architectural sophistication (Højlund 2012; Kjaerum 1983:8-10).

The discovery of the Al-Khidr site by the Kuwaiti-Slovak expedition (2004-2009) on the coast in the northwestern portion of Failaka was also significant. This site has also revealed an early Dilmun influence in the island. This site appears to have served as a port in the early second through middle second millennium BC according to its geographical location and the numerous diagnostic ceramics, metal objects, and bituminous materials encountered (Benediková 2010). The latter three sites yielded various finds and architectural structures suggesting Dilmun dominance on Failaka Island.

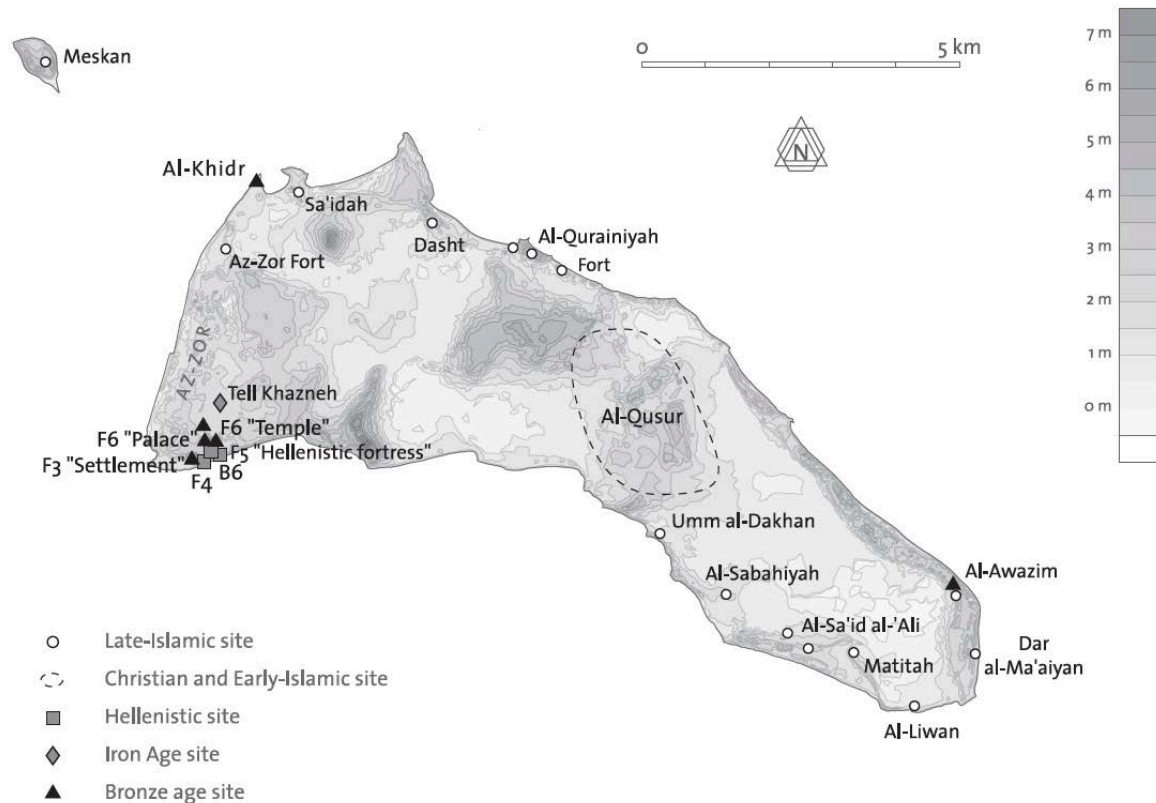


Figure 2.3 Map of Failaka Island showing different archaeological sites and the well-known Bronze Age sites in the western portion of the island (F3, F6 and Al-Khidr) (drawing by H  l  ne David-Cuny).

## 2.3 Dilmun Political Economy in The Arabian Gulf

Before the classic Barbar culture emerged, during the City I period in the late third millennium, there was a similarity between the Period I complex of Bahrain with materials found in the Eastern Province (i.e. Tarut Island, Abqaiq, Dammam) of Saudi Arabia. They shared the certain features, such as the same small and simple burial mounds, local chain-ridge ware. Also, they lacked temples and there were no large settlements or any fortifications (H  jlund 1993, 1994b:468-69). Local pottery in Bahrain and at Tarut had the chain-ridge decoration and the absence of the wheel-made technology has suggested low level skills and specialization and a low level of complexity (Crawford 1998:58; H  jlund 1994b:469). The presence of ceramics

from Umm an-Nar, Ur III, Harappa and Tepe Yahya of the Iranian plateau in the City I period (Edens 1983:39) supports some contact, but a minimum.

The recent discovery of Ur III pottery in a pre-Dilmun complex on Failaka (Højlund 2012), along with the presence of Ur III materials along the Arabian Gulf and Omani peninsula, suggests Dilmun had a miniscule role at that time. Small burial mounds were characteristic of the Dilmun mortuary practices in Bahrain during the third millennium BC. They contained a single primary burial in a stone chamber with evidence of Umm an-Nar pottery and none of any Barbar ridge ware (Crawford 1998:56-57; Højlund 2007:17).

The Eastern Province of Saudi Arabia may have been of great significance to the Dilmun during the third millennium. The presence of various material traditions suggests the presence of craftsmen on the Island and/or extensive regional trade. The decorative steatite vessel is one of the most proliferate type of artifacts present. Its appearance is known for its multi-cultural elements and originated from Tepe Yahya near Kermanshah and Bampur in south and southwestern Iran. The steatite vessels in the Eastern Province were scattered along with jars of buff ware, Jemdat Nasr cylinder seals, and copper bulls' heads from Mesopotamia (Crawford 1998:44-47; Lamberg-Karlovsky 1972). Lapis lazuli stone artifacts from Mesopotamia were also found suggesting the flow of unworked lapis lazuli from Baluchistan or Badakhshan in eastern Iran or the Indian Ocean (Meluhha region) to Mesopotamia (Potts 1993). A number of black-on-red and black-on-gray painted Umm an-Nar pottery and copper fragments, which were also found in the mounds, demonstrate contact with Magan.

The astonishing expansion during the City II or Barbar II period (2050 BC.) marked a distinctive break in many aspects of life. Bahrain replaced the Eastern Province as the center of Dilmun and active port, after an expansion in the settlement pattern. There are 16 sites associated

with this period in comparison to seven sites during Barbar I (Larsen 1983:78). Qala'at of Bahrain became an urbanized area fortified by a small wall extending over 41.7 hectares (Larsen 1983:47). Buildings were built inside the wall on the seaward side and two planned parallel streets lead to the wall gate (Højlund and Anderson 1994). The remains of a group of weights and seals recovered in two rooms from the Qala'at II context have inferred the structure was a customhouse and a town taxation center (Crawford 1998:65). Additionally, the Saar site, 7 km south of Qala'at, contained large residential complexes alongside features of local architecture within what appears to be a street plan. Furthermore, the housing appeared uniform and arranged in a planned layout by the occurrence of an L-shape outer area (Crawford 1998:68-69). The 80 households at Saar were clustered with the burial complex or 'Honeycomb Cemetery' and Saar Temple (Killick and Moon 2005).

Barbar is a stone temple with a double platform level and it has had extensive renovations in the outer works. In phase Temple II, the temple complex was a new constructed building with an oval platform, altars, and stone pillars; also, a pool was built around a fresh-water spring and connected to the temple's center by a stairway (Anderson and Højlund 2003). The platform and chamber was made of a high quality stone that was brought from Jiddah, an island in west Bahrain. Crawford (1998:73) suggested that these well-cut stones and blocks reflect that the craftsmen were very skilled people and were able to transport the stone and smooth the surface. Copper statues of a man, bird, and bull's head at the temple support a connection between Dilmun and Bactria (Turkmenistan) in the early second millennium BC. The ceramic sequence of Barbar II is associated with the base of the first city wall and the absence of Umm an-Nar and Mesopotamian pottery (Larsen 1983:39, 231; Højlund 1994a). Another

incomplete building of a temple was also found in Diraz that was associated with a settlement (Crawford 1998).

Around this period, another Dilmun settlement was raised on Failaka Island, Kuwait. A 20 m square building at Tell F6 was found on a rectangular platform and dated to Period 1-parallel to City or Qala' at Iib. The building has an outer, south entrance, and a paved courtyard. One of the large rooms was filled with copper artifacts (Calvet and Pic 1986). It has been suggested that this building is a temple according to the specially prepared foundation of the building and a well-constructed drain that ran out under the wall. Within the Tell F6, another building was found which is known as the Palace-like structure. Within this structure wall, many local Dilmun vessels were found (Højlund 1987:138) representing the earliest evidence of Dilmun occupation on the island. A Dilmun expansion within Failaka has been noted by the presence of housing complexes at Tell F3, during Period 2. Notably, Barbar wares identical to pottery of the Barbar II period, were found at both the F6 and F3 sites, such as: Barbar red-ridge wares with reverted rims and short necks, red-ridge bowls, and hole-mouthed jars (Potts 1990:274).

Dilmun burial mounds and graves have been used as direct evidence for the growth of socio-political complexity and the presence of a stratified society, during the late third and early second millennium BC. The Dilmun mounds have been divided three categories: (1) single burial mounds, mounds with a central burial connected to subsidiary ones; (2) mounds with a shaft entrance; and (3) finally a burial complex (Crawford 1998; Højlund 2007). The mounds were stone built and the chamber was constructed in a rectangular shape for a single person with a few pots and gifts (Breuil 1999:49; Crawford 1998:80). A typical mound, known as the Early Type, is one to four meters in height and an average of six to ten meters in diameter (Breuil 1999). In

the burial complex, a group of men, women and children were buried together suggesting a burial could have been dedicated to a clan or extended family.

More than 14,000 burial mounds have been identified at Saar, Hajjar, Madinat, and Hamad; additionally, there are very large mounds at A'ali, known as the Royal Mounds (Crawford 1998:80). The spatial distribution and architecture of burial mounds at A'ali, dated to 2200-1700 BC, suggests the presence of a prominent lineage who pronounced their status in Dilmun by the City/Qala' at II period, ca. 2050 BC. Among 70,000 mounds, the 'ring mound' burials represents 46 specimens that have a unique outer ring wall, approximately 12 m in diameter for the burial and 21 m in diameter for outer ring (Laursen 2008). The ring mounds were constructed only in the northern slope of Bahrain's limestone dome and were situated away from other burial mounds. The general distribution of these mounds suggests that they were arranged by size, with the smallest to the south and east followed by a gradual increase towards the north-west to A'ali, dated ca. 2050-1800 BC (Laursen 2008:159).

The wall of A'ali ring mounds range in diameter from 20-52 m to 50-94 m with an estimation of them being 10 m in original height. In the north of A'ali, a cluster of burial mounds was found with a very large ring wall suggesting the emergence of a new status group (Højlund 2007; Laursen 2008). The distinctive Barbar grave pots were only found in these graves along with burial goblets. They were made of reddish fabric with an ovoid body and ridged neck. Dilmun burial jars have also been found as far away as Larsa in Iraq and in southeastern Arabia in Oman; it might possibly have contained a special liquid for burial rites (Lombard 1999a:62). Some exotic and non-local items were found inside the large mounds in addition to the burial jars. Some fragments of an ivory box, a bull's leg, and a fine female figure, which has a known tie to the Indus Valley, were found in these burials (Crawford 1998:85-85).

The Early Dilmun stamp seals are remnants associated with the Dilmun in the early second millennium BC. They are circular, glazed seals that were made of steatite with a high boss on the reverse side, decorated with four grooves, and three incised lines. There is a V-perforation at the foot of the bossing that might be intended for a string or copper ring as a pin or necklace (Kjaerum 1980). The flatter side usually has décor incised on it that includes, human figures, gazelle, deer, horned creatures, or an altar; also, hunting, sailing and feasting scenes. These motifs have a similarity with the Levant, Mesopotamia and the Indus Valley (Kjaerum 1983, 1986). The purpose of these seals is still unknown, but it has been suggested as being used for personal identification, trademarks or badges of office (Crawford 1998). They have been found in Harappan levels at Lothal, Mesopotamian Isin-Larsa level at Diyala Valley and Ur, in Susa of Iran, and at Mazyad in Oman (Cleuziou 1981; Crawford 1998; Mitchell 1986; Potts 1990).

A total of around 800 seals have been found throughout Dilmun's territory, dated to 2000 BC (Kjaerum 1999:116). More than 300 stamp seals were found in Bahrain at Qala'at, Saar, Diraz, and the Royal Tombs at A'ali in the context of the City/Qala'at II, dated 2050 -1800 BC. (Højlund and Anderson 1994; Killick and Moon 2005; Kjaerum 1999). The largest collection of Early Dilmun seals came from Failaka Island. The total recovered from Failaka by the Danish and French expeditions is six hundred seals (David-Cuny and Azpeitia 2012). Among 427 seals found during the Danish excavation on Failaka (1985-63), a total of 292 seals were classified as Dilmun styled seals (Kjaerum 1983); also, 71 seals from the Al-Khidr site; and 95 seals from the Saar site (Benediková 2010a). According to Benediková (2010), the large recovery of seals from Al-Khidr, in a context with large red-ridged jars, suggests that Al-Khidr had been a distributor or a warehouse in the early second millennium BC.

In comparison to the earliest Gulf seals (i.e. greenish circular stone with one or two grooves from the late third millennium), the Early Dilmun seals, dated to 2000 BC, seemed more standardized in terms of the principal shape, style, and decoration. The reverse decoration is standardized with four drilled circles, each two separated by three incised lines (Kjaerum 1999). The variation in seal proportion (e.g. narrow collar vs. wide collar) and profile of the seal rim (David-Cuny and Azpeitia 2012) would imply the existence of a few workshops in Bahrain and/or Failaka. The presence of Dilmun seals alongside other cultural developments suggests that the Dilmun administration attempted to organize trade, to control the market, and/or to collaborate with private individuals and officials. Even though the seals might imply certified authenticity or ownership of goods (Kjaerum 1999; Ratnagar 2004:270), there is an impression of the development of an identification or authorization system required for Dilmun people by 2000 BC.

It is likely that Dilmun intended to express its political and military power, by occupying Failaka, in the wake of Mesopotamia after the collapse of the Ur III dynasty. Culturally, the Dilmun's Barbar culture flourished by 2100 BC and this growth strengthened their position in the trade network. Dilmun's influence over Failaka supported their desire to monopolize the copper trade between Mesopotamian and Oman (Højlund 2007). This expansion is noticeable because of the presence of a new type of architecture, changes in settlement patterns, and cultural materials that required a centralized authority to organize and secure economic activities. In addition to stone works and seals, the change went further to include ceramic production.



## **2.4 Dilmun Barbar Pottery and Craft Specialization**

The shift in pottery production in Dilmun from pre-Barbar to Barbar Period is important to understanding the evolution of ceramic production and Bronze Age craft specialization.

Højlund wrote that pre-Barbar period pottery production during the pre-Barbar period in the third millennium at the Qala'at site was exclusively hand-made, with irregularity and unevenness in the rim, nick, and body regions (Højlund 1994a:175; Larsen 1983). Using remnants from the Qala'at site, Højlund noted changes occurred at beginning of the Barbar culture, 2050 BC. The Qala'at site, as the capital of ancient Dilmun, is vital to understanding the scale of labor, specialization and distribution.

The pre-Barbar period (ca. 2150-2050 BC) is known for the hand-made chain-ridged pottery type (Figure 2.4). The pottery of pre-Barbar is tempered with sand and yellowish-white carbonate particles, known as ware type 1. The color of this pottery varies from red, light brown to gray, with application of a slip to the outer surface. Ware type 1 is the only ware type found at Qala'at in Period 1 or the pre-Barbar period (Højlund 1994a:130). The hand-made hole-mouthed cooking pots comprise 90 percent of the local pottery production in this period (Højlund 1994b:469). It seems Qala'at Period 1 pottery was produced at a household level while all of the decorated wares seemed to have been imported (Crawford 1998; Højlund 1994a,b).

During Barbar Period II or Qala'at IIa (2050 BC.), the rim and neck of handmade Barbar pottery appear more regular, even and symmetric than the pre-Barbar. The pottery use of the wheel technique increased at the Qala'at site and imitations of imported goblets were introduced, inferring the gradual improvements and changes in Dilmun pottery (Højlund 1994b). The wheel-turntable pottery had a limited number of styles and small luxury production, suggesting craft specialization and standardization in production (Højlund 1994b:470).

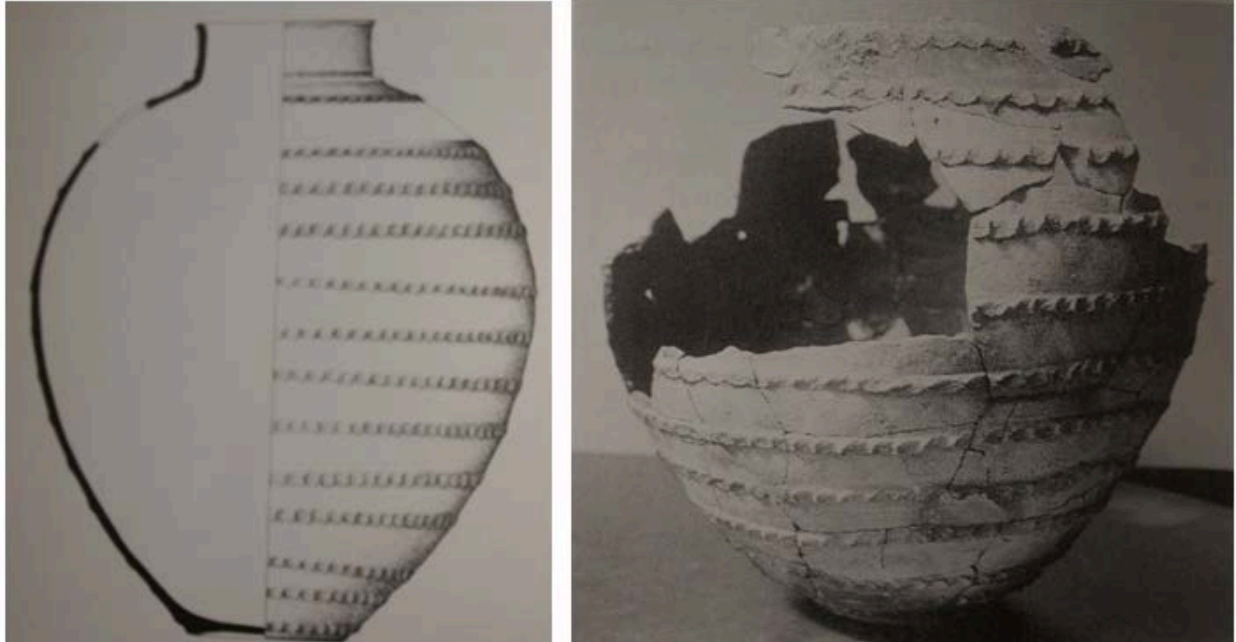


Figure 2.4 Chain-ridge pottery of City 1 at Qala'at in Bahrain (Højlund 1994a:76).

In the Barbar Period (2050-1800 BC), the red-ridged ware, known as Barbar type, became widespread in Bahrain (Figure 2.5). Local pottery production had increased with the decrease in Mesopotamian pottery and disappearance of southeastern (Umm an-Nar) pottery types (Crawford 1998; Højlund 1994a; Larsen 1983). The Barbar pottery comprises 92-98 percent of the total pottery found at Qala'at, with 42 percent of the hole-mouth cooking pot. The percentage of Mesopotamian pottery decreased from 19 to one percent (Højlund 1994a:176). New shapes of pottery were developed in this period and other shapes became more prevalent. For instance, the Mesopotamian and Omani pottery at Qala'at were replaced by the new shapes of the Barbar tradition (e.g. type B7, B21-23, B29-30, B62 and B68). These wares showed innovations occurred in pottery function (bowl and plates), technique (wheel-made), and shape such as large rim and ring base (Højlund 1994a:176).



Figure 2.5 Red-rimmed jars as a characteristic of the Dilmun assemblage during Barbar II or City II (Moon 2005:280-81).

In Failaka, Højlund (1987) has classified the Dilmun ceramics of the earliest phase into four types (i.e. 1A-C, 21, 38A-C and 44) that came from the context of Period 1 that is contemporary to Qala'at Iib, ca. 1950 BC. Barbar ridge vessels with a thicker triangular rim (i.e. equilateral and vertical rims), known as type 1A-C, are characteristic of Period 1. Also, the bottomless cylinder vessel (type 38A-C) and the ridge vessel with a tapered rim are identical to wares of Failaka's Period 1. Other types have been dated to Period 2 (type 14, 15A and 32) with a plate type that has different rim variants (Figure 2.6).

Some Barbar Period wares were red-brown and hand-made while others were yellow to yellowish-red and wheel-made. Both of the latter have a feature of a yellowish slip covering the outer surface. Painted pottery was introduced in this period, both local and imported, particularly the 'Eastern Tradition' wares from the Iran-Indian border (Crawford 1998; Højlund 1994a; Larsen 1983). The very distinctive Barbar type wares have been found on Failaka Island, representing a wide range of Barbar wares, including neck or neckless ridged jars, plates, goblets, bowls, and cooking pots. They have been dated to Failaka's Period 1 or Barbar Period

IIf, with forms and fabric development that lasted until the end of Period 2, ca. 1730 BC.

Højlund (1987:103-107) has noticed that there are five fabric types among Dilmun pottery. The diagnostic fabric type A-, B-, C-, and D-ware are the dominant types in the research samples selected from the Bahrain and Failaka assemblages (Figure 2.7).

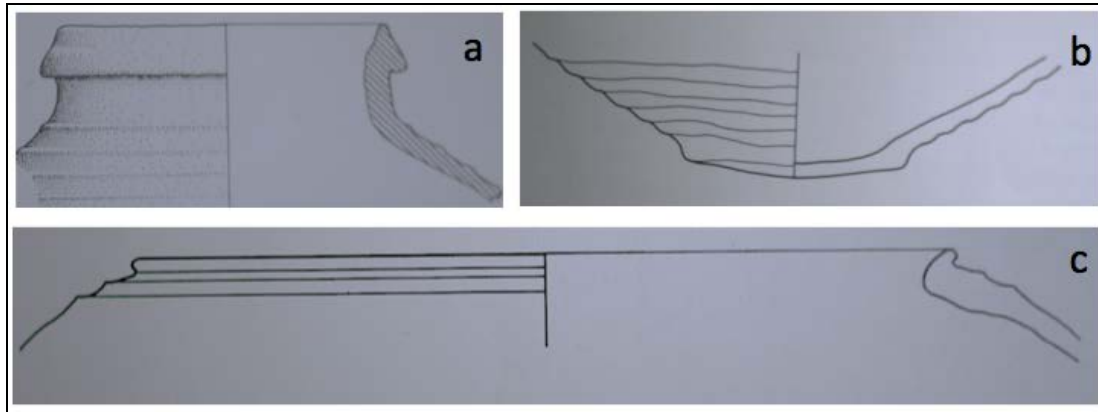


Figure 2.6 Development of various types of Failaka pottery in Period, type 1B (a), and Period 2, type 32 (b) and type 14A (c) in the early second millennium BC (Højlund 1987).

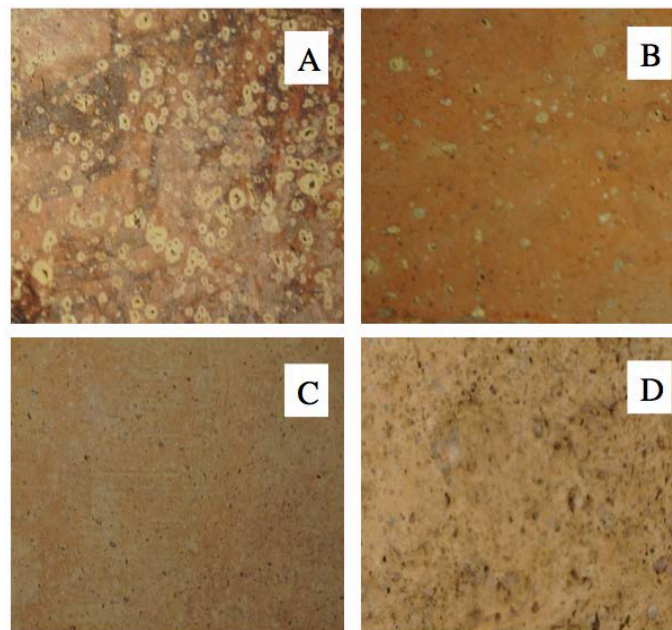


Figure 2.7 The four dominant fabric types (A, B, C, D-ware) of Dilmun pottery found in Bahrain and Failaka (photo by Hasan Ashkanani).

The first type of Barbar ware is A-ware, which is characteristic of most pottery dated to the early second millennium BC on Failaka and in Bahrain. This type of pottery is sand-tempered, well fired, hand-made, and the colors are homogenous. This type of reddish ware is strongly tempered with sand and white-yellowish lime particles (Højlund 1987:103). In the center of these particles is a hollow area, seen as irregular rounded spots, which probably arose from firing lime. Another feature of the A-ware type is the clear lamination in the fabric. It seems that it consists of flakey layers cemented together and partial cavities between them (Figure 2.8). This ware, according to Højlund (1987), can be divided into sub-groups based on different colors: (1) red ware with red slip; (2) red ware with whitish slip; (3) red ware with grey slip; (4) ware with both grey and red that for instance have zonation as a red core sandwiched between two grey zones, grey cores sandwiched between two red zones, or gray outer and red inner surfaces (Figure 2.9).



Figure 2.8 Sample no. 13609 as A-ware type of Barbar red-ridged pottery showing lime particles in the outer and inner surfaces. Notice artificial white lines on the edge (left) showing thin flakes of lamination (photo by Hasan Ashkanani).

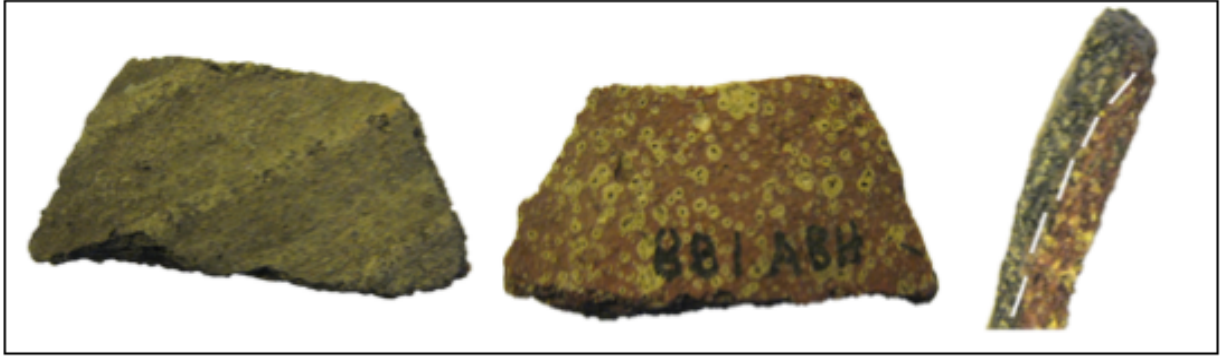


Figure 2.9 Sample no. 13628 as Barbar A-ware type of grey outer and red inner surfaces. Notice white dots on the edge (left) showing two zones (photo by Hasan Ashkanani).

The second type included of Barbar ware is B-ware that is also well fired and similar to the A-ware type but lacks hollow lime particles. The lime particles can still be seen but without a cavity or are smashed and shattered (Figure 2.7B). The color is also red like A-ware but with more yellowish and brownish or light reddish-brown to a light red. Also, the Barbar C-ware type also belongs to hand-made production as type A- and B-ware but is not harder than the others (Højlund 1987:105). This type is a distinct a feature of site Northeast Temple APR and Qala'at IIF in Bahrain and F3 Period 2 on Failaka Island. It is medium-tempered with finer particles (Figure 2.7C). The core is yellowish-red to reddish-brown with a gray or red slip. The color is homogenous, more yellow in color, and lacks lamination. The outer surface has a whitish-grey and red slip like the others and some with more light green yellowish slip. Most of the C-ware sherds are hand-made and some sherds of this group have been thrown, having finer tempered grains (Højlund 1987:105). The Barbar D-ware type, which represents very few sherds from later periods on Failaka Island, also belongs to the hand-made Barbar tradition, also, these wares are well-fired, medium-tempered and relatively hard ware. According to Højlund (1987:105), D-ware types lack lacks lamination but the outer surface is usually eroded, leaving the outer surface slightly raised (Figure 2.7D). Within those ware types, there are three fabric types that are



associated with the Mesopotamian tradition (i.e. E-, F-, G-ware). Fabric type E- and G-ware are predominant among the presumed Mesopotamian pottery (Figure 2.10). Fabric types A- and B-ware are the most predominant types among Dilmun pottery in Failaka in Period 1 and 2, ca. 1950-1800 BC while C-ware is the common type in Period 2B (ca. 1800-1730 BC) when wheel-made wares increased to 9% (Højlund 1987:111-117). D-ware replaces A- and B-ware and becomes as common as C-ware during period 3A (ca. 1730-1550 BC) as a development break in both fabric type and pottery form (Højlund 1987:121).

The lack of archaeological evidence of workshop locations could hamper the study of the scale of pottery production and craft specialization. The existence of pottery kilns and workshops in association with a particular settlement pattern could provide an insight into ceramic production. Whether the specialist was full time or part time, independent or attached, the development of Barbar pottery techniques suggest significant changes that reflect the existence of skilled craftsmen and specialists in Dilmun during the early second millennium BC. The research background on sociopolitical complexity, craft specialization and trade/exchange in the Near East is presented in the next chapter in purpose to contextualize how these concepts can be used in the Bronze Age of the Arabian Gulf.



Figure 2.10 Two Mesopotamian fabric types for wheel-made vessels, yellowish pink E-ware and pale greenish straw impression G-ware (photo by Hasan Ashkanani).

## **CHAPTER THREE: RESEARCH BACKGROUND**

### **3.1 Introduction**

Studies in the Near East and adjacent regions have centered around three main avenues of interest, such as social complexity and power, craft specialization, trade/exchange networks. Early twentieth century excavations in Mesopotamia, Iran, Indus Valley and later in Syria and Turkey (Matthews 2003:32-66) spurred archaeologists to develop some approaches to characterize the socio-political entities of these regions and their economic development. Currently, socio-political complexity is linked to craft specialization, settlement patterns and architecture, trade networks, and subsistence shifts. In this chapter, I explore the hypotheses and interpretations made regarding power and social complexity, craft specialization, and exchange and interaction in the Near East and the Arabian Gulf, introducing various research efforts relating to political, social and economic development. Also, I include the various materials used as a vital evidence for interpretation. Finally, I contextualize these concepts and the interpretations of the larger Arabian Gulf region.

#### **3.1.1 Key of Power and Social Complexity**

The oversimplified evolutionist approach has colored our understanding of social complexity and political power. Ancient societies do not always fit into these neat categories (i.e. band, tribe, chiefdom, state, etc.) defined by kinship, subsistence types, and technological innovations (Service 1975). Norman Yoffee (1979) argues that evolutionary approach failed to



present a unified theory that takes into consideration for internal processes of social change. Notions surrounding social complexity and power have replaced evolutionism and provoked an examination of how power is exercised within a socio-political structure, such as decision-making, control of technological development, individual agency, socio-cultural meaning, and subsistence shifts.

Yoffee examines the collapse of social and political system in Mesopotamia during the Old Babylonian period (ca. 2000 -1600 BC) as the result of changes in the decision-making process. After the city-states period and the fall of the “Third Dynasty of Ur”, Hammurabi unified central and southern Babylonia economically and politically establishing a centralized administration and law codes for legitimating the interaction (Yoffee 1979:12). Later, the empire could not supply the people with enough food and acquire resources particularly after the loss of some territories and revenues accruing, which made the power of the crown weaker. Therefore, Yoffee argues that the collapse of Old Babylonia was due to the failure to maintain and integrate locally autonomous controls within and among city-states; it was a balance loss when local groups asserted their autonomy and political control away from the state control (Yoffee 1979:14). According to Yoffee’s conclusion, there was no evidence regarding outside competition (e.g. Anatolian Hittites vs. Babylonian Kassites), and failure to adapt to an environmental change was a cause of Old Babylonian collapse as Service’s evolutionary approach. However, Shennan (1982) and Sherratt (1982) argued for the correlation between geological and environmental variety and social complexity in Neolithic Europe and through the Bronze Age.

Similar to Yoffee’s decision-making concept, Henry Wright (1977, 1978) and Gregory Johnson (1975) attempted to explore sociopolitical organization and complexity scale at state

level based on technology production. They established that fourth millennium seals, sealed bullae and sealed items from Iran are evidence of specialization and administrative bureaucracy. Moreover, the distribution of these seals in the Middle and Late Uruk in Northern Iraq, Assyria, and southwestern Iran, ancient Elam, indicates the administrative control on the movement of goods from the production centers to assembly points and then to central administration. This interpretation is supported by the discovery of invoice records from a Middle Uruk site in southwestern Iran, Susa, in which these records were sent to centers for checking at higher authorities; and in turn the commodities were redistributed from these high authorities and centers down to the level of production centers (Wright 1977; Wright and Johnson 1975). Thus, administration and power seemed to be strengthened through the control over production, exchange, and redistribution of goods either by the state, elites, or officers under the control of a central authority. The redistributive hierarchy has been attributed to the chiefdom as a level of socio-political organization that was exercised in Neolithic communities in Near East (Lamberg-Karlovsky 1975) and in early European through Bronze Age Minoan and Mycenaean economies (Galaty 2011; Renfrew 1972; Service 1962). Recently, some works have focused on the different materials as an administrative technology. Clay seals from the Late Neolithic Sabi Abyad site in Syria indicate the administrative control on sealing production by high status people or elites (Akkermans and Duistermaat 1997).

Administration is not the same as power. Administrative power in the Neolithic Southwest Asia is understood as an increase of social stratification between a group of people in order to solve inter-groups disputes by pulling them into surplus food production, public feasting, and gift-giving (Matthews 2003:89-90). Galaty et al. (2011) provides a collection of papers that explores the role of palaces “palatials” as an administrative agent for exchange and

redistribution in Bronze Age Minoan and Mycenaean economies. Moreover, archaeological artifacts from Uruk colony sites in Syria and Anatolia suggest administrative control on trade and exchange by Mesopotamian administration in the fourth millennium BC. Wood products, copper, and precious metals were imported from Syria-Uruk sites (i.e. Habuba Kabira, Jabal Aruda, and Shiekh Hassan and Anatolian Hacinebi Tepe, etc.) by Mesopotamia for exporting material to the north such as textiles and finish bitumen artifacts (Algaze 2001; Schwartz 2001; Stein 1999, 2001, 2002). Similarly, Polanyi (1957a) suggested that we should explore centralized administrative control over economy and exchange, the *substantivist approach*, to understand the socio-political structure of the society.

Robert Adams (1974) emphasized the role of individuals and private entrepreneurial exchange. For instance, the absence of any evidence of connecting the Cappadocian merchants (*gal-dam-gar*) in Anatolian Kultepe site with the Old Assyrian administration suggests a certain level of autonomy for individuals to pursue private activities for economic gains. Supporting the Adams' concept of agency, Veenhof (1972) also argued for the private entrepreneurial exchange of silver and gold held by Assyrian merchants with Assyrian commercial settlements (*Karum*) in Anatolia.

Stein and Rothman (1994) argued for an integrative approach that accounted for economic, ideological and political organizations. Also, they wanted to explore the degree of centralization and interaction as dynamics of social complexity. They supported the use evolutionary typologies, “chiefdom” and “states”, as analytical terms to address organizational variation rather than define a structural type (Rothman 1994:4). Therefore, Stein (1994) argued that the combination of textual and archaeological data still supported the traditional approach.

How power was exercised within ancient socio-political structures is not a new facet to exploring social complexity. Social complexity can include the role of heterogeneity, agency, competition, and cooperation among different groups within Mesopotamia rather than just reflecting the bureaucratic and administrative organization of Mesopotamian polities. Using “power” alone as a model to unravel any socio-political organization can be problematic because, in case of Mesopotamia, states exercised different degrees of power over spaces. Stein (1994) argued that Mesopotamia state institutions could not exercise power both within and between urban centers. For example, through the presence pastoral nomads sites, goods produced by sedentary villages in Mesopotamia, Syria and southeast Turkey, archaeological evidence seems to support this limitation of extended control. To understand the socio-political development in Great Mesopotamia, researchers should focus at several different levels of analysis such as the temple and palace sectors, households, regional and intra-site interaction and patterns of consumption, production, and exchange (Rothman 1994; Stein 1994). Hodder (1990) argued for the importance of ideological power as a key to unraveling socio-political development, particularly regarding subsistence shifts in Southeast Asian and Europe. For instance, the shift to a sedentary lifestyle was a result of a change in human culture that occurred prior to the adaptation of agriculture; furthermore, the houses reflect this symbolic power and their distributions represent social relations (Hodder 1990:294). Therefore, the chief Neolithic villages in the Near East (i.e. Jericho, Catalhoyuk, and Tell Abu Hureyra, etc.) include structures and buildings that reflect the symbolic development of social identities and reproduce social relations (Hodder 1982). The decorated buildings “shrines” and paintings of bulls’ horns at Catalhoyuk (7200 BC.), a structure used for ritual ceremonies at Jericho (8500-7300 BC), and

red paint at Tell Abu Hureyra shows the degree of symbolic and ritual complexity of Neolithic communities in the Near East (Scarre and Fagan 2008:61-63).

Schwartz argued for the role of elites' power and their control over local agricultural surpluses in the development of sociopolitical organization. Schwartz (1994) argued that elites of complex chiefdoms in Syria and northern Mesopotamia in the early third millennium BC (i.e. late Chalcolithic Age) increased their power by controlling surplus staples that are collected from population and stored by elites, who in turn used such for exchange or personal benefit. The scale of centralized storages from middle Khabur plains sites, such as Raqa'i and Atij, relative to the small local population, indicates the intentional storage for exchange and consumption elsewhere. A close examination of cylinder seals at the Raqa'i site- items that served as a symbol of high status and administrative authority- has shown that these seals have central Mesopotamian stylistic and thematic as well as pronounced local characteristic. Seals could be emulated with foreign technology and style for social and political expression. Syrian and north Mesopotamian elites sought to legitimize their position; perhaps, the control of granaries was a precursor to intensive control over trade and exchange in a burgeoning urbanized, state (Schwartz 1994). Timothy and Sara Champion (1986) showed that Iron Age central European chiefdom elites have owed some power by controlling salt and metal ores for exchange with other peer-polity societies and also with Mediterranean, Rome, from sixth to fourth century BC. The local rulers, theoretically, emphasized the importance of controlling mobilized goods from the producers to the foreign political entities. The mobilization could be reflected in the level of specialization and interregional exchange in terms of political developing and enhancing the patronship of elite in certain craft specialties (Brumfield and Earle 1987:3).

Rather than focusing on elite control over resources and agricultural surpluses that may permit a centralized system to propagate complexity, William Sumner (1994) examined settlement patterns and land use of fifth millennium society in the Kur River basin of southwestern Iran. He considered evidence of agricultural pursuits and irrigated fields to investigate the development of socio-political organization. His hypothesis was that social, political and economic organizations could be understood in term of society's population, which increases the scale of interaction, productive specialization, and the level of decision-making hierarchy (Sumner 1994). Thus, studying settlement patterns provide valuable insight into the sociopolitical organization pattern and its change through land and use of space over time; it involves large and different dimensions of social and economic organizations.

### **3.1.2 Craft Specialization and Social Complexity**

Archaeologists have used craft production and specialization to explore the scale of sociopolitical organization, hierarchical relationships in the economy, and the role of elites in long-distance exchange in the Near East and its adjacent regions. Blackman et al. (1993) utilized standardization hypothesis that the degree of standardization of archaeological material- such as ceramics- can be useful to distinguish specialist-produced utilitarian goods from non-specialist household and to identify the scale of power and centralization. For example, the dimension, technology and chemical composition of the third millennium ceramics from the urban site of Leilan in northeast Syria were studied; and the results show a high consistency and homogeneity of production in the vessels. Identifying the degree of standardization provides a meaningful avenue for understanding the scale of craft production and specialization as well as the form of socio-political organization. Stein and Blackman (1993) focused on the organization of utilitarian

and prestigious craft production in Mesopotamia and Syria from early Ubaid to late Uruk periods (5500- 3100 BC.) in order to discuss the degree of power wielded by chiefdom versus a state. Moreover, Pollock and her colleagues (1996) focused on the Uruk ceramics from the Uruk Mound of Abu Salabikh in southern Mesopotamia to reconstruct the economy of Uruk period in southern Mesopotamian (fourth millennium BC.). The results indicated that manufacture of ceramics and stone tools for processing animal and plants were widespread and not organized or controlled by centralized institutions (Pollock et al. 1996). It seems that stone tools and pottery production and use were considered utilitarian goods during the Uruk periods with no evidence of direct control by a centralized institution or elites. The organization of utilitarian craft production in states seems to be uncontrolled by institutions but in the hands of independence specialist- and that shows a high degree of variation. The evidence from Mesopotamian and northern Syrian in the Early Bronze Age suggests dual-natured economy in which specialists attached to centralized institutions produced prestige goods and utilitarian items for consumption by palaces and temples, while independent specialists in the cities and villages produced utilitarian goods for non-elite consumption (Stein 1996, 1998; Stein and Blackman 1993). The continuity of administrative craft specialization and production occurred apparently in Mesopotamia during the Iron Age, particularly in the first millennium BC. Concurrently, the Neo-Assyrian state monopoly controlled wool extraction, production and traded with the Phoenician coast where wool was woven and shipped back to various parts of the Near East (Galvin 1987:127). Along with textual evidence, the camel seems to be controlled in the Iron Age by the Assyrian empire that had utilized it for heavy transport over long distance. Moreover, Assyrian control had been extended to include livestock (i.e. goat, sheep, and cattle herding) after the environmental degradation to the supply threatened both economic security and

population. The faunal remains from Terqa, in the Middle Euphrates region, showed an increase in the number of cattle and decrease in goats during the Iron Age suggesting the decision to rely on cattle as more valuable economically for market exchange and for providing renewable resources (Galvin 1987).

The scale of craft specialization in Indus Valley is considered an avenue to understand socioeconomic organization at Harappa and Mohenjo Daro in the mid-third to early second millennium BC. Vidale (1989) compared the distribution of vitrified debris of pottery and waste of stoneware bangles at Mohenjo Daro. The distributional pattern suggested that stoneware bangles were distributed in only two areas reflecting the scale of production as prestige good and attached specialists to elites of an administrative institution. Moreover, the distribution of pottery debris was distributed in a clustered pattern across the site indicating dispersed workshops of independent craft specialists (Vidale 1989:172-178). Even though there is evidence of small and domestic workshops within each settlement, the craft production in the ancient Indus Valley cities, particularly in Harappa, Mohenjo Daro and Dholavira, was apparently highly organized. The official supervision and control of production can be seen in the small scale in the distribution of quarters dedicated to a particular crafts and also in large scale in the pattern of settlements (town and villages) that surrounds the major cities and close to the source of appropriate raw materials; each single or group of towns seem to be as exporters of raw materials or finished goods and specialized in particular products such as copper tools, shell products, and steatite seals (McIntosh 2008:262-263). Ethno-archaeological studies of Indus crafts have provided insight into the indirect control over some crafts such as ceramics, agate, shell working and steatite bead (Kenoyer 1984, 1986, 1997). For instance, ethno-archaeological studies have shown that the several techniques of agate beads perforation and different drillings in Khambhat,



India, reflect either distinct ethnic communities of bead makers with a hereditary techniques or reflect hierarchies of workshops (Kenoyer 1997:272). Using different techniques for producing certain local material for the purpose of reflecting social status and hierarchy is an advantage of Harappan elites; who wanted to maintain their complete control over resources and artisans with no need for long-distance exchange as a factor of maintain the complexity (Bhan et al. 1994:143-144). Recently, evidence of long carnelian beads distribution and drilling technique suggests the Harappan elites control over the beads' and the internal interaction and local redistribution among ancient Indus urban centers production from the mid-third to early second millennium BC (Kenoyer 2008a, 2008b). The intensive dependency on local resources and internal interaction controlled by the bureaucratic and administrative institution within the Indus Valley region could explain the 'logic' for the small size of storage facilities and also support the meager distribution of grains, raw materials, and finished goods. The storage facilities (i.e. the warehouse at Lothal, bins and jars at Kuntasi and Gola Dhoru) suggest that the facilities were temporary for keeping goods and materials or probably guarded while in transit between producers and consumers (McIntosh 1998:264). The control of some craft production and material distribution is of the key factors for understanding the sociopolitical and economic growth in Harappa. This development was noticed in particular during Period 3A where the dominant elite group, regional alliance were established and new materials (i.e. chert weights, new ornament and ceramic style) were made as correspond to the development of socioeconomic and political organization (Kenoyer 1991:57).

### **3.1.3 Trade, Exchange and Interaction**

Various models have been proposed to determine the nature of exchange and interregional interaction among different socio-political entities, including: the large-scale perspective to define the pattern of long-distance contact and dominance; and the small-scale perspective to focus more on the role of agency and ethnic groups in the interregional interaction. Even though long-distance exchange of luxury goods has been associated with the socio-political organization of chiefdoms (Junker 1990; Peregrine 1991), it is useful not to strictly adhere to notions that correlate the trade and mechanism of exchange with a certain socio-political organization (Lamberg-Karlovsky 1975:341-343). The measurement of any economic behavior should be examined through interdependent variables that are demand and supply, facility of transportation, and nature of commodities (Lamberg-Karlovsky 1975). Therefore, most works in the Near East have been focusing on prestige goods, long-distance, exchange and interregional interaction, with no strictly correlation, from two theoretical frameworks: 1) world-system model that focuses on the large-scale power and interaction; and 2) internal dynamics that focuses on small-scale interregional interaction emphasizing the role of agency, ethnic groups and the peripheral polities.

World-system model has been utilized to understand the nature interaction of Mesopotamian, Syrian, Anatolian and Iranian highland complex societies particularly from fourth to second millennium BC. The aim of applying the world-system model is to understand the exploitative relationship between the core and periphery in order to answer questions regarding raw materials, commodities flow, and trade and exchange process between Mesopotamian and Anatolian city-states (Algaze 1989, 1993; Allen 1992; Ekholm and Friedman 1982; Larsen 1987). The actual evidence pertaining to trade networks in the Near East does not

conform to the parameters of this model. Theoretically, this structure would have empowered the position of the Mesopotamian core (Uruk and later Assur), enhanced the position of elites, and strengthened the city-state economy by acquiring raw materials for manufacturing finished goods. For instance, Akkadian (2250 BC.) and Old Assyrian (1900 BC.) textiles were being exchanged with Susa (Iran) and Afghanistan for precious and semi-precious stones, Anatolia for silver, and Magan (Oman) for copper. However, archaeological and textual evidence does not support any homogeneity of Mesopotamia over, neither Magan nor Susa. Magan was an independent entity that traded with Mesopotamian and Indus Valley for supplying turtles (for meat and shells), leather, and copper (Larsen 1987; McIntosh 2008). Archaeological evidence from mid-third millennium site (Umm-an-Nar period) of eastern Omani Coast Ras's al-Junayz yielded copper stamp seals with a Harappan design and inscription, Harappan pots, a Harappan ivory comb as well as a quantity of solid bitumen imported from Mesopotamia (McIntosh 2008:175-177). Thus, Oman had an active role in the trade network. Moreover, the pre-Uruk contact evidence in southern Anatolia suggests that Mesopotamian was not a necessary catalyst for Anatolian social complexity (Stein 1999:102-106).

Marfoe (1987) argued for the importance of understanding the effect of long-distance linkage on social change. For instance, the socio-political development within Egypt after the unification of Upper and Lower Egypt, around 3150 BC, led to an expansion to the Levant, particularly Byblos (Lebanon). Egyptian-influenced and imported-Egyptian objects have been attested and possibly were obtained by Byblite elites. The sea-going ships may have led to exercise intensive trade and exchange between Egypt and the Levant for grape during Old Kingdom (ca. 2686 -2160 BC.) and olive oil during New Kingdom period (ca. 1550-1069). Moreover, the archaeological and textual evidence provided better insight on interaction between

Egypt and the eastern Mediterranean in the Late Bronze Age, at the end of second millennium (Liverani 1987). The sea trade in the Late Bronze Age had brought Egyptian fleets, a fleet from Alasia-Cyprus, a Mycenaean fleet, and one from Ura in Cilicia together for trade and exchange in metals specially Maggan-Oman and Alasia-Cyprus copper, Syrian timber, olive oil and purple-dyed wool textiles; the Ugaritic ships from Syro-Palestine were restricted by Mycenaean political units to have direct contact with the central Mediterranean and Europe and thus reached southward to the Syro-Palestinian harbors (Liverani 1987:66-86). The Egyptian and Mycenaean monopoly was broken-down in the Iron Age when gold, myrrh and incenses could reach Syria and Jordan directly from Yemen through caravans routes originated and developed by Southern Arabia settlements such as Hijjaz (Liverani 1987:72-73). Thus, the growth of nobility or bureaucracy and centralization in the Old Kingdom of Egypt, particularly during Dynasties V and VI (Marfoe 1987:27-28) provided an opportunity to connect with “peripheries” for controlling the resources. Moreover, the presence of caravan routes in southern Arabia in the Iron Age could be understood as a shift from administrative trade and exchange or palaces (as in Egypt and Uruk) to individual enterprises with no account for fixed price or times as seen by administrative economy. Thus, Liverani (1987) suggest studying the trade terminology (e.g. *mhr* vs. *mkr*) that could reveal a change in meaning from Bronze Age to Iron Ages and that indicates to a shift in the economic organization.

World-system’s assumptions have been criticized and modified in order to clarify the scale of political entity and interregional interaction. Core-periphery hierarchy and unequal exchange relationship in world-system economies have limited understanding the dynamics of an interaction between Near Eastern polities and central Asia particularly in the Bronze Age. Kohl (1987a) argued that the Bronze Age settlements of Bactria, stretched in southern Turkmenistan,

northwestern Afghanistan, and southern Uzbekistan, interacted with South Asia and Iran in the late third millennium with no core-dominant meaning. The settlement pattern, mortuary evidence, and transferable technologies (metal working and horse breeding) support the Bactria was self-sufficient without technological gaps that which might led to depend on core economy, as world-system model suggests (Kohl 1987a:16-23). Instead of reliance upon Harappan metal weapons, Central Asian Margiana and Bactria rapidly adopted and transformed these technologies in order to establish interaction and political relation with other regions in the Near East.

In contrast to Algaze's discussion on world-system of Uruk-Anatolia and large-scale interaction perspective, dynamics of interaction between Uruk colonial traders and Anatolian communities in the fourth millennium BC have been examined from the small-scale perspective that focuses more on the local communities, social identity and agency. Stein (1999, 2002) suggested that trade-diaspora model supports the study of social identity and interaction between Uruk and Anatolia during Chalcolithic Age in the fourth millennium BC. The model suggests that there is no homogeneity over faraway regions and the states incorporate with different ethnic groups or colonies that settled in the host community and lived side-by-side with maintaining their own cultures. New types of ceramics (Uruk style), architectural features, cylinder seals, and bitumen materials at Anatolian site of Hacinebi Tepe support the presence of long-term Uruk diasporic communities who desired to trade and exchange with local Anatolian communities and may have played as middlemen to transship non-Mesopotamian goods to the local elites at Hacinebi (Stein 1999, 2002). The symmetric and autonomous economy of both local groups and Uruk merchants reject the world-system model's assumption of unequal exchange and core dominance and rather support the role of peripheries and local individuals in structuring power

and organizing interaction network. Veenhof (1972) and Larsen (1976) focused more on the role of individuals and independent agents as a remarkable feature of old Assyrian trade at Anatolian Cappadocia in the Bronze Age of second millennium BC. They asserted that the merchants acted as independent agents with no control of Assyrian administration in exchange of textiles, silver, gold and copper. Veenhof (1972) and Larsen (1976) were the first break from the traditional view of old Assyrian colonies and administrative economy that utilized administrative trading colonial system between old Assyrian and Anatolia in the second millennium BC. (Derksen 1996; Helwing 1999; Orlin 1970; Özgüç 1950, 1953, 1959, 1999; Polanyi 1963). Thus, the latter studies focused on: 1) the scale of power and dominance (administrative vs. individual enterprises); 2) the development of secondary states as a result of interaction and long-distance with states (core and peripheries); 3) elite strategies for maintaining power and status; and 4) interaction within communities, giving realistic sense of understanding the development of socio-political organization and trade and exchange of different materials.

#### **3.1.4 Role of Ceramics with Other Materials**

With this intensive interaction between different regions, ceramics were very important to reconstructing relative chronology and cultural variation of the Near East. Studying different types of pottery, the association between ceramic typology, seals, and buildings has shown that a relative chronology for multi-component sites, particularly for the Bronze Age Dilmun sites in Failaka Island and Bahrain, is useful to understand the interaction between Failaka and other regions. Conducting comparative studies of ceramic typology, seals, and buildings (Bahrain and Kuwait), archaeologists found it possible to find parallels between Bahrain and the many types of pottery from Failaka Island (Højlund 1987; 2007). The pottery from Bahrain was obtained

from 2 periods of Qala'at (period II and III), while the Kuwait ones obtained from tells F6 and F3 sites. Based on various types of different parts of ceramics along with stratification, the pottery from Qala'at were divided into 6 periods (IIA-F) for Qata'at II and 2 periods for Qalat'at III. For instance, the first period, Qala'at IIA is characterized by plain jar rims, plain hole-mouth rims, yellow jars with red wavy lines, and ridged body sherds more than chain-ridged, while in period IIb triangular rims with convex upper surface were common (Højlund 1987:151-152). Using Bahraini stylistic database as a reference allowed to reconstruct the chronology of ceramics and occupation of the buildings at Failaka Island; the results was a division of 7 periods that reflect chronological and cultural variation extended from 2000 – 1300 BC. (Højlund 1987:157:158). Discovering two Ur III cylinder seals at F3 site at level 6.50 m, the dating of period 1-2 confirmed the picture received from the earliest Mesopotamian pottery (Højlund 1987:157). The presence of ceramics together with a seal impression at the Barbar Temple in Bahrain similar to seals and seal impression found in early Failaka seal style, period 1, confirmed the chronology and coincidence of both Failaka's period 1 and Barbar Temple IIb (Højlund 1987:158). More test excavations at different trenches and sites clarify the picture about the chronology, occupation, and cultural variation.

### **3.2 Socio-political Organization, Trade and Exchange in Kuwait and the Arabian Gulf**

Identification of Neolithic sociopolitical and economic organizations in Kuwait and the Persian Gulf in general is still implicit due the lack of farming, domestication and settlement (e.g. mud-brick) evidence. Evidence from Saudi Arabia (KSA), Bahrain, Qatar and Oman has documented 'Paleolithic' presence (50,000 -20,000 BP) of lithic tools in Yabrin oasis and Jabal Midra ash-Shamali in Saudi Arabia, Al-Markh in Bahrain, Ras Uwainat Ali in Qatar, Fahud and

Natih in northern Oman (Potts 1990:28-31; Vine 1993:14). The late Neolithic and early Chalcolithic period in the Gulf has been identified by the presence of Ubaid-type pottery (5500 - 3800 BC.) that are widely scattered in Ras Abaruk (Qatar), Al-Markh (Bahrain), As-Sabiya (Kuwait), Dosariyah, Abu khamis, and ain Qannas in Saudi Arabia (Bibby 1969:376; Cardi 1986; Carter 2002; Carter and Philip 2010; Carter et al. 1999; Oates 1986; Potts 1990:40-52). Most of these works have focused on the subsequent identification of Ubaid pottery (period 1 to 4) in order to determine the Ubaid cultural zones and the movement of Ubaid materials. Recent excavations in Ubaid site of as-Sabiyah in north Kuwait Bay provided insight into the nature of these settlements outside of Mesopotamian Ubaid, particularly in the Persian-Arabian Gulf. The results from showed the presence of Ubaid 3 pottery (ca. 5300-4300 BC.), obsidian objects and tools such as blades, disk beads and fishtail objects (Healey 2010), bitumen samples with vegetal impressions such as reed and barnacles (Carter 2006). The discovery of sixth and fifth millennium BC bituminous coating seafaring reed boats (Cannon et al. 2005), ceramic model boat, as the earliest remains anywhere of sea-going boats (Carter 2006), indicate the early maritime exchange relationship between Ubaid communities of southern Mesopotamia and the later Neolithic/early Chalcolithic groups of the Gulf. Carter (2006) argued that the distribution and context of Ubaid pottery in the Gulf indicate that this pottery carried connotation of wealth and high status and therefore the pottery may have redistributed in acts of ceremonial gift-giving or exchange within Arabian Neolithic/Chalcolithic society. More evidence (e.g. faunal and flora, seals) should be obtained to focus more on the scale of specialization and communication between specialists (e.g. fishers, hunters). It has been important to focus on the large-scale interaction between Ubaid groups in the Gulf. Future studies should go beyond identifying the boundary of Ubaid and long-distance interaction to shed light more on the interaction across the



shorter distance. For example, Carter and Crawford (2003:88) identified the source of bitumen used at as-Sabiyah and it comes from the Burgan, south Kuwait. Thus, studying the scale of interaction could include the mode of human movement and land use within a small scale (coastal sites in the Gulf and inland sites of Arabia), as well as the consideration of ideological and religious activity in this interaction and exchange.

In my opinion, these concerns should be also raised for the Bronze Age archaeology of Arabian Gulf to understand the nature of socio-political organization, craft specialization and labor organization, and the role of ideological power in development of Gulf complex societies. I would divide the archaeological studies for the Gulf during the Bronze Age (3000-1100 BC.) into two thematic tendencies. The first approach and tendency has been focused on the Gulf during third and second millennium BC illuminating the broad cultural relations and occurrence of interaction between Mesopotamian (Akkadian, Jamdet Nasr and Early Dynastic periods), Iran (Tepe Yahya, Shahri-i-Sokhta, and Susa), Dilmun (Bahrain, Kuwait and eastern Saudi Arabia), Eastern Arabian settlements in Hilli (United Arab of Emirates/UAE) and Magan, and Central Asia (Cleuziou 1986; During-Caspers 1994; Lamberg-Karlovsky 1972; Méry 1989, 2007; Rao 1986; Weisgerber 1986). The second tendency has been to reconstruct chronological schematics by typological analysis of Gulf ceramics and identify the extension of Dilmun power or culture in different portion of the Gulf (Andersen and Højlund 2003; Højlund 1986, 2007, 2012; Laursen 2008). The presence of only Dilmun ridged red pottery and Dilmun stamp seals (Benedikova 2010; Højlund 1987, 2007) in the earliest Bronze Age site in Failaka Island (F6, the Palace) supports the absence of Mesopotamian control on Dilmun. The control of Mesopotamia on Dilmun may have occurred on Failaka Island, Bahrain, and Qatar in the second half of second millennium (1450-1200 BC.), attested by Kassite building at Qala'at site in Bahrain, ceramics at

F3 site in Failaka Island, and ceramics at Khor Ile-Sud in Qatar (Edens 1986, 1987, 1994, 1999; Højlund 1987). Eden's works (1986, 1987, 1992, 1994) could be the only synthetic and speculative attempt to push the theoretical boundary of the Bronze Age archaeology of the Arabian Gulf. Similar to Uruk colonial groups' controlling the resources and trade route in Syro-Anatolia in the fourth millennium BC, the Kassite expansion was motivated more by controlling commodities and extracting agricultural surplus from Dilmun of Bahrain and Qatar (Edens 1986).

After the collapse of Kassite, Harappa and later Elam, archaeological records do not provide tangible evidence of the any socio-economic interaction and urbanization in the Gulf during the Iron Age, until the eight century BC, with the presence of local regional ceramic traditions in Bahrain and Oman. The Iron Age in the Gulf is associated with the presence of Neo-Assyrian materials with textual reference to Tilmun (Dilmun) by Neo-Assyrian kings, who also listed goods available in the southern marshes such as copper, elephant tusks and sissoo wood (Edens 1986; Reade 1986:334). Some evidence suggests Neo-Assyrian and/or Neo-Babylonian pottery at Qala'at of Bahrain but with no definitive chronological indices (Lombard 1986).

The discovery of more than 600 Dilmun circular stamp seals (Gulf seals) on Failaka Island and in Bahrain (Benedikova 2010; Crawford 1998; Kjaerum 1983, 1986) potentially provides a substantial body of evidence. The continuity of various elements and symbols (i.e. gazelle, alters, palms, beer drinkers, etc.) engraved on Dilmun stamp seals could be a tactic of maintaining symbolic and ideological control to enhance the political organization of Dilmun. Researchers can use the seals' iconography as a way to gage the level of centralization, system of law, administration and the power of ideology. A variety of questions could be raised for future research. Was the expansion of Dilmun (Bahrain) to Failaka in 2000 BC motivated by the

‘ideology of unity’ of territory or people (Krader 1968:10), or was the Dilmun temple of Enzak on Failaka Island a significant religious loci of ‘collectivity of society’ (Krader 1968:10)? Was the ‘ideology of unity’ of Dilmunites in the third and second millennium BC a mechanism to control the maritime route? The direction for future research should include critical questions and developing methodologies that encompass ideology and power, cultural variation, human movement and agency along with socio-economic organization. In the next chapter, I review the attempts that aim to build a theoretical framework in the Near East and adjacent regions to understand the sociopolitical complexity, craft specialization and interregional interaction.

## **CHAPTER FOUR: THEORETICAL BACKGROUND**

### **4.1 Introduction**

Archaeology came of age in the twentieth century (Stiebing 1993:109-118) with European expansionism and the exploration of the Near East and Egypt. Archaeological interests grew beyond simply collecting the past and cartography to include the proposal of theoretical models, deciphering languages, and the implementation of standardized field techniques. In this chapter, I review the history of archaeological studies of exchange and interaction in the twentieth century to shed light on the development of theoretical studies in the Near East and adjacent region. Diffusionism and nineteenth century Evolutionism were being overturned as impractical explanations for archaeologists (Trigger 1989) that continued to make discoveries within Europe and around the world. Trigger (1989:148-150) would write that archaeologists became desirous of reconstructing cultural history, such as identifying ethnicity through artifacts, the development of artifact taxonomies, the development of local chronologies, and exploring the idiosyncratic nature of cultural change. Diffusionism was not sufficient to explain independent technological development of the same invention by different cultures; also, evolutionism could not explain invention and innovations synchronically, cross-culturally.

Renfrew and Bahn (2000:351) wrote that the exchange of materials and information are central to present-day archaeological studies. Some archaeologists would concoct 'fanciful criteria' (Trigger 1989:149) at times to establish ethnic identity, invention, and innovation while others would rely on historians, cultural anthropologists, and ethnologists, such as: Bronislaw

Malinowski, Franz Boas, Marcel Mauss, Karl Polanyi, and Immanuel Wallerstein.

Archaeological studies of the twentieth century are marked by: 1) the exploration of socio-cultural interactions that undergird trade and exchange; 2) the use of new scientific techniques to characterize artifacts; 3) the study of production and distribution of material goods; 4) and the impact of trade and exchange on culture change (Renfrew and Bahn 2000). I discuss the development of archaeological studies in exchange and trade highlighting the most influential theoretical frameworks, such as: early culture-history, acculturation, and Polanyi's triad and substantive approach. I also discuss environmental determinism, redistribution model, concept of agency, the world system theory, and peer polity concept. I conclude the theory and model that would be applicable to my work on ceramics, indicating to the role of pottery and other materials to answer my research question.

#### **4.2 Socio-cultural Interactions that Undergird Trade and Exchange**

Cultural anthropologists and sociologists had a tremendous influence on the archaeological studies of trade and exchange in the early twentieth century. Bronislaw Malinowski's *The Argonauts of the Western Pacific* (1922), and Marcel Mauss', *The Gift: The Form and Reason for Exchange in Archaic Societies* (1923; Eng. trans. 2000) provoked a plethora of discussion on trade and exchange. Functionalists sought to analyze the institutions that lent to social cohesion. Malinowski's was interested in the economic behavior of peoples that spanned a region of islands, Melanesia, and how goods peacefully moved from island to island. He found an elaborate network of exchange partners that principally exchanged valuable items and secondarily everyday necessities in the context of public ceremonies. His work would become part of the foundation of trade and exchange studies. He determined that the generosity

and public nature of presenting gifts (i.e. size of feasts, rituals, giving of valuable gifts, etc.) supported social standing and prestige (Renfrew and Bahn 2000). Alliances, disputes, and other social matters are settled by “Big Men,” those prominent in the Kula Ring from ostentatious giving. Furthermore, Mauss’ wrote of the obligatory nature giving has and the social implications attached to it. For example, Northwestern American Indians during their summer festivities, potlatches, intensifies and carries a ‘notion of honor’ (Mauss 2000:35). Honor is defined clearly as unabashed, generosity as well as reciprocating in quality in an obligatory amount of time to those who give. He found that the rank and authority of a chief is maintained by the potlatches (for himself, his son-in-law, daughter, and his ancestors). He must prove that he is favored by the ancestors and spirits by giving or he loses his soul and other associated rights over the people (Mauss 2000:39); it is tantamount to losing a war! Socio-cultural ideas about honor, spirituality, kinship, rank, and time all undergird economic behavior.

Archaeologists would begin to define the parameters of their studies with workable theories and models that could be tested in the archaeological record. In the 1950’s, Karl Polanyi would build on the latter scholars’ works to discuss the types of exchange that we can establish within the archaeological record: *reciprocity, redistribution, and market exchange* (Renfrew and Bahn 2000). He defined reciprocity as exchanges that take place between individuals that are symmetrically placed; redistribution as a system in which goods flow through a central organization and are redistributed to participants; and a market exchange in which transactions can occur in a central location or ‘port of trade’ and social relations are secure enough to negotiate (Renfrew and Bahn 2000:354). Furthermore, Polanyi (1957a:226) defined exchange as the “mutual appropriative movement of goods between hands” and these hands can be supported archaeologically; also, an interaction that is recognizable through the presence of different exotic

or foreign objects and materials in the archaeological site. Renfrew defined trade or exchange as reciprocal traffic or “movement of materials or goods through peaceful human agency” (1969:152). Lamberg-Karlovsky (1972) claimed that trade and exchange are similar but the latter is “lacking a definite organization or standardized value for specific material” (1972:222). It is a way to acquire goods peacefully from a distance either directly or through from a place or middlemen/individuals to another. Implicit in this discussion is the discerning which products were “valuables” (i.e. tokens of wealth and prestige) and which were “commodities” (i.e. necessities) to the sphere of exchange (Renfrew and Bahn 2000:355). Participants within a sphere of exchange determine what is valuable and what is are commodities.

In addition to the culture-history approach, *acculturation* is one of the earliest conceptions fostered by archaeologists to understand trade and exchange. It is another concept that was proposed to explain interregional interaction and the dominance of Europeans on other societies. Redfield et al. (1936) presented the concept of acculturation as a phenomenon in which two different cultural groups of individuals come into continuous first-hand contact that result in a change in either or both of the original cultural patterns. Acculturation can be seen in social and political inequality between groups; furthermore, it implies that the acculturated socio-cultural group desires to bring ideas, materials or any advantage of a more powerful socio-cultural group for prestigious or economic advantages. The result of acculturation is the loss of cultural traits of a small group but it is able for bridging the gap between two groups (Herskovits 1937). Noticeably, early explorers were interested in examining culture contact and its effects on social developments. Captain A.W. Stiffe (1897) has reported a description of some ancient coast settlements that served as emporiums or commercial centers in the Arabian Gulf. He specifically reported pottery scattered in Bushire (Iran) and al-Qatif (Saudi Arabia), Bahrain islands, and

their role during Babylonian time. Later, Okun (1989) used the concept of acculturation as a direct measure of detecting the Upper Rhine archaeological materials, particularly pottery assemblage, during the early Roman period. Carter and Philip (2010) argued that the disappearance of Halafian culture in North Mesopotamia in the Neolithic Age, toward the end of sixth and early fifth millennium BC, was due to the acculturation of powerful Ubaid culture traits. Melas (1991) also found that acculturation is a valuable concept of understanding the technical and economic innovation of the flourishing Aegean peripheries (e.g. Telos, Thera, Melos) during the first half of second millennium BC. For instance, archaeological (i.e. pottery, metals works, architecture, weights, etc.) and epigraphic evidence has demonstrated the Minoan impact and control on cultural materials in the region; also, a proposed increase in social complexity by the adoption of the superior Minoan technology and cultural features. The change of different aspects of pottery such as form and style is associated with involving more powerful donor culture in the local society, such as Egyptian-influenced objects in Byblos (Lebanon) after the unification of Lower and Upper Egypt in the late fourth millennium B.C. (Marfoe 1987). This approach has been meaningful to evaluate a social and cultural change that has occurred as a result of interaction between local people and the Romans as well.

*Environmental determinism* as a model was proposed in the fifties by some scholars to discuss trade and exchange. Particularly, Graham Clark studied prehistoric European culture with an emphasis on the economic behavior, beginning from Paleolithic to the appearance of farming communities in the Neolithic Age. Clark pointed out that the environment or the external nature is the key to understand the “development of culture that is viewed in its economic aspects” (1952:7). Thus, there should be an equilibrium and stability between culture and the environment to insure economic stability that is the normal condition for any prehistoric



society. This equilibrium can be disturbed by various factors such as, climatic changes and its effect on subsistence strategies, the pressure of population on available food supply, and the impact of human activities on the relationships between various forms of wild life and humans. Prehistoric Europe witnessed ecological transformations due to shifts to environmental pressures, such as: subsistence shifts, storage of materials, and ultimately trade and exchange with other groups. With evidence from the archaeological record, Clark (1952) wrote that prehistoric Europeans maintained shells and other objects of personal adornment as the earliest trade objects. Archaeological evidence showed that trade was carried out in materials needed for weapons, including flake from Belgium, Holland and Scotland, obsidian from central and south-eastern Europe, and axe and adze blades from north-western Europe (Clark 1952). Clark's work characterized prehistoric European economy as an environmentally deterministic barter-based system. His examination of the aspects of commodities exchange and direction of consumption would become another cornerstone of archaeological studies of trade and exchange.

The *substantivist approach* was very appealing due to Karl Polanyi's (1957b, 1963) theoretical contribution. Polanyi suggested that a particular emphasis for trade and exchange studies could be the exploration of *market exchange* with a focus on a centralized administration, the substantivist approach. Polanyi believed that the concept of economy is implicit and vague because it is embedded in non-economic institutions, cultural systems that rely on reciprocity and redistribution. Non-economic institutions and the transactions in individual hands are very difficult to discern in the archaeological record; such factors (e.g. unknown transaction level, serving agent, lack of quantitatively, and unidentifiable physical site of trade and exchange) that prevent better understanding of economy in ancient societies. When a centralized organization or institution controls the economy, the process of economy produces a stable structure with a

definite function of society that contributes significantly to the history. Thus, it is a “human economy” that is embedded in institutions that make scholars easy to follow any economic process at different places and times.

Institutional exchange, according to Polanyi, is a system of trade with a medium of exchange and market; also, implicit are parameters for the movements of goods and a standard set rate; thus, a competition between partners. Polanyi found out that this approach was applicable to ancient Mesopotamia, Greece, Maya and Aztec markets, and for pre-contact Africa societies. On the contrary, the Assyriologist Oppenheim (1964) denied Polanyi’s redistributive and administrative economy of Assure and ancient economy of Mesopotamia. The textual evidence and cuneiforms documented the private activities and non-administrative exchange (market). I shall discuss later how Near Eastern archaeologists adopt an aspect Polanyi’s market exchange concept, port-of-trade, as alternative model for understanding the details of economic institutions and interaction in Mesopotamia, Persian-Arabian Gulf, and Anatolia.

Archaeologists specializing in prehistoric Africa and India adopted Polanyi’s substantive approach in the 1960s and early 1970s to explore at what social tiers trade and exchange is controlled and to examine various economic aspects, such as price structure. Their aim was to reconstruct the trade and exchange systems in prehistoric India and Africa (Bohannon and Dalton 1962: Leeds 1968: Neale 1957, 1962). Also, they were interested in pre-colonial African era commercial networks and the degree of inter-relatedness to political and social institutions (Gray and Birmingham 1970). Elman Service’s (1962) work drew a correlation between a pattern of trade and a specific level of social complexity. For example, Service defined *chiefdom* as a distinctive type of social complexity in which the chief redistributes the wealth he receives as gifts; thus, he is the central artery of exchange. Service concluded that exchange between two

different geological zones required a leadership to carry out this process with others. This control results in social inequality among members of society and consumption patterns reflect the social inequality as well. Service wrote that there are no particular technological innovations associated with the “chiefdom” social organization and archaeologists may not be able to identify such a site in the record.

In archaeology, Earle (1977) attempted to evaluate chiefly redistributive hierarchy in primitive economies, particularly pre-contact Hawaiian chiefdoms by adopting redistributive mobilization typology. Earle found that the major environmental differences among different districts of a Hawaiian chiefdom resulted in differentiated subsistence strategies. Furthermore, these districts contributed different specialized products (e.g. fish, meat, dried taro and tobacco) to the trade network under the control elites. Also, these elites used their prosperity to support a destitute population and finance elites’ political and private activities. Thus, Earle concluded that redistributive mobilization is a recruitment of service and goods to benefit elite’s activities and somewhat the non-elites. In recent *AIA* Forum section by Galaty et al. (2011), there is a collection of papers that explores the role of redistribution in Bronze Age Minoan and Mycenaean economies. Galaty et al. emphasized the role of palatials (palaces) as centralized redistributive agents of elite goods. It was suggested that elites collected raw materials and allocated them to specialists to add value to them through skilled labor and then redistributed by palatial mobilizers to an exclusive group/elites as recipients.

Robert Adams (1974) introduced the concept of agency as an alternative approach of Polanyi’s institutionalized economy in ancient and non-western societies. His argument was based upon the absence of institutional and administrative textual evidence from Assur (Ashur) for trading with Anatolian Cappadocian colonies (i.e. copper and tin). The lack of evidence

connecting the *gal-dam-gar* (the merchant) socially or politically to the state or temple administration implies a level of autonomy for individuals to pursue entrepreneurial activities for economic gain. Adams insisted that the private entrepreneurial exchange could be supported based on a different line of evidence. For example, records from Girsu, an ancient Sumer city north Lagash and contemporary tell Telloh, around middle of the third millennium BC, indicated some individual shipments of ten tons of grain and various amount of different materials sent to Dilmun (Bahrain) to be exchanged for a copper. Another record indicated a household merchant receiving 13,300 processed fish from fishermen. Adams concluded that archaeologists should not ignore the role of individuals or groups, their goal-motivated behavior for economic entrepreneurship, and their effect on trade and interaction in the complex societies. Moreover, Veenhof (1972) also veered away from Polanyi to argue that there is substantial in Babylonia for retail merchants who carried out their private activities in a small *suq* or bazaar. Moreover, Veenhof contested Polanyi's (1957c) assessment of the Assyrian commercial settlement in Anatolia, *Karum*, with evidence supporting that the exchange was for silver and gold by the merchants for the state (1972:350).

Generally, analyses of trade in exchange would include a combination of various economic aspects (e.g. exchange, redistribution, and reciprocity) with other systems such as political economy, long-distance, level of social complexity, specialization, ranking and source dominance. Furthermore, these works focused on the pattern of community models (e.g. gateway model) that maintained the trade market in ancient Mesopotamia, Mesoamerica, and Southeast Asia from the fourth millennium BC. Renfrew (1972) detailed the redistributive model and its relationship to social hierarchy. His arguments were based upon the socio-political organization of Aegean civilization. He proposed, in Sabloff and Lamberg-Karlovsky's 1975 edited work, ten

different modes of exchange and interaction based on spatial analysis. One of his most influential models is the “down-the-line” model. This model traces the movement of a commodity from one group to another as it moves further away from the source. Also, the further distance from the source, one should expect a decline in the quantity of the commodity and an increase in its value. The location of decline is called spatially, “the contact zone” (Renfrew 1969, 1972).

Scholars were interested in determining the interaction pattern in relationship to spatial pattern for ancient societies. There was a proliferation of studies in the late 1970s (Hirth 1978; Lamberg-Karlovsky 1972; Sabloff and Lamberg-Karlovsky 1975) that discussed the effect of distance on interaction, and the role of long distance trade and regional economies on the emergence of market centers. Also, Sahlins’ (1972) comparative analyses, attached cultural and social contexts with the economics of exchange and communities’ interaction.

The most renowned model is the world system theory (WST) proposed by Immanuel Wallerstein during the 1970s. Wallerstein (1974) built his ideas on an analysis of colonial Europeans’ expansionism and their spheres of economic influence. He suggested first that no polity could develop in isolation. Furthermore, the political and economic development of a state is contingent upon trade relations with other polities. Wallerstein’s theory has been applied to the analysis of modern history as well as ancient societies. WST assumes centralized socio-political organization and the management of trade and exchange, locally, regionally, and inter-regionally. Fundamentally, the WST model has been used to explore large-scale, unequal economic interactions between a state and other polities in its trade network.

Wallerstein outlined the WST model to describe a network based on production and exchange; the dominance of powerful states of a region (cores); and the exploitation of less powerful states (peripheries or semi-peripheries) by cores. Wallerstein (1974) outlined three

zones comprised of distinct political units involved in a trade network, with each performing at a different level of interaction and political power. The first zone, *Core region*, is at the upper echelon of the WST social hierarchy. A *core* is a highly political, centralized unit that has productive resources, military force, and an accumulated surplus (Stein 1999). This centralized authority allows the core to dominate and control trade and exchange with other cores or peripheries. The core usually influences change in the periphery by exporting its technology, ideology or culture. *The periphery region*, the second zone, is less powerful than the core and has very few resources and less specialized labor. The peripheries are dominated by the cores, which acquire raw materials from the former and then import them back as finished products. Peripheries lack a strong centralized organization, such as they cannot control their borders, they have a weak military force, and they have weak local rulers (Stein 1999). The third zone is *the semi-periphery region*, which is a combination of the core and periphery. It is less complex than the core but centralized and has a sociopolitical hierarchy. It might have a core or a periphery structure or intermediate institutional features of both (Chase-Dunn and Hall 1993). Elites of the periphery would be involved at the interregional level of interaction and then pull their region into a more complex and powerful state. However, this development relies on supplying raw materials to the core, which in turn controls the periphery by supplying finished products and controlling the exchange system. The world system theory has encouraged archaeologists to look at different scales of political entities, to examine how secondary states develop in relation to a core, and consider external and internal factors that promote growth in the trade network.

Many Mesoamerican archaeologists have argued that there was a world system in Mesoamerica that encompassed the southwestern United States. Mesoamerican archaeologists (Whitecotton and Pailles 1986; Peregrine and Feinman 1996; Peregrine 1996; Kowalewski 1996)

have published their ideas about the prehistoric interaction and exchange system of Mesoamerica. Over centuries from pre-classic to post-classic, Aztec dominated the peripheries and connected them by importing preciosities from its peripheries and exporting general goods. Aztecs traded salt, cotton, cocoa, maize, fruits and gourd bowls in return for more exotic materials from its peripheries (Xicalango and Soconusco) such as gold, silver, precious stones and ocelot skins (Whitecotton and Pailes 1986:188). These interactions extended into the southwestern peripheries whose elites were looking to obtain prestigious goods. Moreover, the demand for prestigious goods drew the attention of the Mesoamerican core to exploit the peripheries and bring them into a dependency relationship (Whitecotton and Pailes 1986:194).

General criticism of core-periphery relationship and asymmetrical exchange between polities in WST (Edens 1992; Stein 1999, 2002; So 1990) led archaeologists to modify the theory to be more applicable for a pre-capitalist system (Chase-Dunn and Hall 1993, 1997; Hall et al. 2011; Kohl 1987a, 1987b). These modifications included discussions on the avoidance of intersocial inequalities, exploitation, and hegemony to explain interaction as incorporative between stateless and complex societies. Urban and Schortman (1999) attempted to modify the core-periphery relationship by arguing the possibility of ideological exchange between core and periphery, going beyond the materialist world. The evidence from the late classic Naco Valley, southern Mesoamerica, shows that core dominated peripheries by flowing ideological innovations, such as beliefs and ritual practices to maintain the dependency relationship (Urban and Schortman 1999:137–139). Reminiscent of Hodder's postprocessualist approach of exchange is a way of creating meaning in action (Hodder 1992).

Another influential modification to WST aimed at explaining the role of exchange in socio-economic change was the peer polity interaction model (Renfrew and Shennan 1982;

Renfrew 1986). The peer polity interaction model does not assume dominance and subordination between polities (Renfrew and Bahn 2000) but considers that all polities of the system are parallel and of approximate equal status and that the exchange takes place between autonomous parties (Renfrew and Sherry 1986). This model allows an analysis of the symmetrical exchange between parties of equal power and the inclusion of the socio-cultural elements of exchange, such as symbolic entrainment, ceremonial exchanges, and ritual activities (Renfrew and Bahn 2000). Archaeologists have used the peer polity model to address the dynamic abilities of polities, formerly considered peripheries, to affect network interaction and societal change. Notwithstanding, peer polity interaction can be used to reconstruct a spatial pattern in an exchange system and identify organizational changes.

#### **4.3 Exchange and Interaction in the Near East and Adjacent Regions**

Near Eastern archaeologists have used different theoretical analyses and approaches to recognize that exchange and interaction between various societies inside and peoples outside the Near East regions. These analyses grow significantly after and intensive excavations in Anatolia, Indus Valley and within the Near East (Matthews 2003:32-66) to understand social and cultural context of various economic aspects, particularly from the Neolithic Age to the late Bronze Age and early Iron Age. These periods witness a sophisticated revolution in all different aspects of human life starting from political development and urbanization to extraordinary economic and cultural interaction. Based on important finds, therefore, archaeologists have been working on providing models illuminating the rise and decline of these cultures and highlighting the dynamics beyond this interaction.



Based on the above discussion the history of archaeological studies of exchange and interaction in the world, I shall discuss which approaches have been employed in the Near East and adjacent areas. I would divide the different theoretical frameworks into three tendencies of exchange and interaction: 1) direct exchange and the colony trade, 2) indirect trade and central place model, 3) world system model, and 4) trade diaspora as a testable model for understanding the movement raw materials between Mesopotamia and Anatolia.

Archaeologists have utilized some aspects of Polanyi's concepts and his analysis of administrative economy to develop the *colonial networking concept*. The third millennium Mesopotamian textual evidence from the Early Dynastic III period (ca. 2520 BC.) proclaims the ruler Ur-Nanshe as having received wood from foreign lands as a tribute. The textual evidence associated with Sargon of Akkad (ca. 2334 BC.) indicates that he achieved a real economic advantage in the Persian Gulf circa the third millennium BC. He received commodities directly from Oman and Indus Valley- notably without the middlemen of Dilmun (Larsen 1983:33).

Archaeologists have relied on these data as evidence of direct contact trade between Mesopotamia and Indus either by sea (Oppenheim 1954) or by land (Mallowan 1965). The direct contact trade requires the presence of X people in Y place. The movement of X people to Y place without any intermediary places/sites can accomplish the direct contact. The X people could control Y place and settle in; a colony. This type of trade can be for specific materials and usually administrated and organized by one of the groups involved (Lamberg-Karlovsky 1972).

The colonial networking approach has been widely used to discuss the nature of interaction during Neolithic and Chalcolithic periods (6500-3800 BC.) between: 1) south Mesopotamian Ubaid and north Mesopotamia of Syrian and Anatolia (Frangipane 2001; Stein and Ozbal 2007; Thuesen 2000); and 2) Mesopotamian Uruk and Syria, along with Anatolia in

the Chalcolithic Age; and 3) the Bronze Age Assyrian colonies in Cappadocia, Anatolia (Algaze 1993, 2001; Larsen 1976; Orlin 1970; Özgüç 1950, 1953; Stein 1999, 2001; Veenhof 1972). The colony model is considered a valuable approach to interpret Mesopotamian Uruk in the Levant during the late fifth and fourth millennium BC. The nature of this type of interaction suggests long-distance administrative control of emissaries and imperial planning by Uruk leaders within Syrian and Anatolian polities. Stein (1999, 2002) shows how the distinctive Mesopotamian Uruk material cultures (bitumen, ceramics, architecture, ornaments, and seals) at the late Chalcolithic Age Hacinebi Tepe, South Anatolia along the Euphrates, are the signatures of the presence of a small Mesopotamian colonial enclave inside the local Anatolian region. Moreover, the northern portion of the area includes jar seals, jars stoppers, clay tablets, and a hollow clay ball filled with tokens illustrating the presence of standard Uruk administrative authority. These administrative artifacts and Mesopotamian communities are also common at other Syria-Uruk colonies such as Habuba Kabira, Jabal Aruda and Shiekh Hassan, yielding a presence of communities and people from southern Mesopotamia rather than a diffusion of objects and ideas (Schwartz 2001). Archaeological evidence supports the Uruk importing of timber, wood products, copper, precious metals and semiprecious stones. It has been suggested that the exported materials to the north included textiles, agricultural commodities and finished bitumen artifacts (Algaze 2001; Stein 1999, 2001, 2002).

Even though there is substantial evidence of exchange and interaction, some arguments have devalued the economic imperatives and the primacy of trade as a motivating factor of Uruk expansion and colonization. Colonial networking may have been interwoven with the strategy of elites to obtain and secure resources for political and ideological purposes (Algaze 2001). The trade colony as a key of direct trade may be completely inappropriate model for the Uruk

expansion toward the north. Helwing (1999) argued that the chaff-tempered pottery from Late Chalcolithic Hassek Hoyok, on the left of Syrian Euphrates River, is no more than the pronouncement of cultural identity and affiliation by local Syro-Anatolian craftsmen, who seemly had an intensive contact with Uruk culture and imitated some features of Uruk pottery. Despite the controversy regarding the aims of Uruk trading colonies, there is agreement with regards to the establishment of Assyrian colonial trade and network along the main trading routes.

The second millennium BC. Old Assyrian *karums* in Cappadocia, Anatolia, is one of the best archaeologically documented, administrative trading colonial systems, where the foreign traders live alongside the indigenous people. Textual and archaeological evidence from three colonial sites at Cappadocia (i.e. Kultepe, Hattus, and Huyuk) support the distinctive activities by foreign traders or colonists who settled in their own quarters and maintained their own religious and secular matters (Derksen 1996; Orlin 1970; Özgüc 1950, 1953, 1959, 1999). These individuals represented the Assyrian government in commercial and administrative matters to the Anatolian rulers and maintained Assyrian control over a larger network of settlements in Taurus under the supervision of *ummeanu*, the home offices in Assur. The home officers were able to control silver, gold, copper and textiles trade in Anatolia (Derksen 1996; Helwing 1999; Orlin 1970). Veenhof (1972) and Larsen (1976) were the first to break from the traditional view of old Assyrian “colonies” and Polanyi’s administrative and fix-price economy. Polanyi (1963) argued that the Assyrian trade at Cappadocia could exemplify an institutionalized market and a system of port-of-trade; the merchants were governmental agents who carried out trade based on fixed prices and commissions (Polanyi 1963; Adams 1974). Veenhof (1972) and Larsen (1976) asserted that Assyrian State influence was minimal and that Assyrian agents acted as

independent agents in a market economy. For instance, Veenhof pointed to less state and administrative exchange based on textual evidence that contained a statement to Assyrians to sell “at any price” (*batiq wattur*); thus, policies existed that supported agent-based decisions and individual enterprises at Cappadocia (1972:88). The numerous references to the importation of Akkadian textiles to Anatolia support the notion that there were independent transactions and different sets of agents covering the transport; it is difficult to estimate the economic investment of the state institutions of Ashur and the degree of its control on profits (Adams 1974).

Some archaeological evidence has been deemed insufficient to infer anything about any face-to-face or direct trade contact in the Persian Gulf. Lamberg-Karlovsky (1972) argued that the presence of Indus seals, etched carnelian beads, terracotta status and dice in Mesopotamia could not be used as an evidence for the direct contact. Nor does the presence of Mesopotamian reverse-slip ceramics, segmented beads, or spiral and animal head pins support the direct contact with Indus. There is no evidence of Mesopotamian seals found in Harappa, nor a distinctive Mesopotamian architectural complex in the Indus, the reverse being true (Lamberg-Karlovsky 1972). Even though the occurrence of Indus objects and seals has been documented, they are single finds that do not support the existence of colony trade. On the other hand, the distribution of Predynastic Naqada pottery (4000-3200 BC.) in urban sites of southern Palestine suggest the desire of Upper Egyptian rulers to gain direct commercial contact with Palestine without the middlemen of Lower Egyptian (Shaw 2000:321). Archaeologists have had to discuss the significance of single finds and other anomalies that imply contact and trade.

Many archaeologists support the indirect exchange and interaction between Mesopotamian and the Indus Valley based on the presence of Mesopotamian and Indus artifacts on sites, such as: Dilmun, Tepe Yahya (Iran) and Magan (Adams 1974; Kenoyer 2008a:

Lamberg-Karlovsky 1972, 1975; Larsen 1983, Ratnagar 2004; Weisgerber 1986). For example, Ur III tablets do not mention the Magan of Oman and Indus people in Sumer nor are Mesopotamian people mentioned in the Indus Valley. This lack of evidence seemingly supports the notion of indirect trade. Coupled with the presence of single finds and there arises the implication of Dilmun control over the maritime route and the commodities that were produced from Oman included onions, goats, oil, reed, wood, and copper or from Indus Valley as sissoo wood (Weisgerber 1986:138). On the other hand, the expansion of Elam during the third millennium BC prevented the direct contact overland between the Indus and Mesopotamia. Also, the presence of Indus materials (e.g. weights and seals) and Omani copper metals on Dilmun of Bahrain has implied the Dilmun control over the Gulf particularly in the second millennium BC. Therefore, Lamberg-Karlovsky (1972) proposed that Central Place Theory could offer a theoretical framework of interaction between Elam-Mesopotamian-Indus entities.

The Central Place Theory purports that there are a few central points that produce and offer consumable goods and services; thus, consumption occurs at many scattered areas by transshipping. According to this model, Tepe Yahya (Iran) was one of these central places that controlled natural resources (e.g. steatite) and the land route while Dilmun (Bahrain) was another central place in the Gulf that controlled the transshipment of goods rather than control of resources, particularly after the collapse of Akkad (2150 BC.). The expansion of Tepe Yahya prevented the Indus from having a direct contact with Mesopotamian. Moreover, the absence of port sites in the third millennium along Iranian shore of the Persian Gulf is indicative of the Elamites control overland and their hostility (Lamberg-Karlovsky 1972). Also, the absence of the port could be as a result of Sargon of Akkad's power extended over the Gulf in the second half of third millennium BC. For example, textual evidence reads, "the ships of Meluhha, the ships of

Magan, the ships of Tilmun (Dilmun) he moored at the quay in front of Agade” (Larsen 1983:33). This might indicate the Akkadians’ control over the gulf and the embodiment of Bahrain and Iranian shore ports in Mesopotamian political structure- a loss of middlemen during this period. Elamites may have been too intimidated to establish any port during Akkad era.

The application of the Central Place Theory has its limitations and it is not clear how to use archaeological materials to reinforce the indirect exchange with Mesopotamia based on this theory. Limiting the role of Dilmun as a place of transshipment or as a warehouse would restrict our understanding of the role of agency and the political and social organization of the polity. This theory acknowledges the development of these polities, who were involved in the interaction between two or more “big” actors, as a result only of this indirect trade; thus, without the demands of the outsiders, the places and polities would not be raised and urbanized. On the contrary, Kenoyer (2008a) wrote on the role of the internal exchange on the development Harappan urban centers. Based on the analysis of drills used to manufacture long carnelian beads and their limited distribution at the sites of Mohenjo Daro, Harappa, Chanhudaro, and possibly at Dholavira, Kenoyer (2008a) suggested that certain merchants of elites were controlling the beads produced by them. Also, their limited distribution suggests an intra-regional network during the Harappan period (2600-1900 BC.) and interaction at the local level occurred within a stratified-based network. Kenoyer (2008a) supports the role of local redistribution in the rise of urban centers instead of indirect, long-distance trade with Mesopotamia.

The archaeological data from Mesopotamian and Anatolian pre-state communities and ancient complex societies has led archaeologists to apply World System Theory (WST) to explain a number of factors including: the core–periphery relationship (Peregrine 1996); raw material and commodities flow, trade and exchange process (Mair 2006); and social

development and cultural diffusion (Algaze 1989, 1993; Allen 1992). Ekholm and Friedman (1982) thought that this theory could answer questions about the nature of the scale of interregional interaction between early Mesopotamia and Anatolia city-states, from the third to second millennium BC. They attempted to explain Mesopotamian expansion from the imperialist approach of world-systems theory; imposing a picture of an exploitative relationship between the core and periphery. This exploitation empowers the position of the core to increase its wealth and economic competition by controlling peripheries to acquire raw materials for manufacturing finished products (Ekholm and Friedman 1982). Other archaeologists (Algaze 1989, 1993; Allen 1992) have also argued for the continued use of the WST model in the ancient Near East, particularly with the expansion of the first Mesopotamian urbanized polity (Uruk) in the fourth millennium BC and its control over neighboring regions in Anatolia and Iran. They have argued that this system continued into the second millennium BC when Assur traded tin and textiles for gold, copper and silver with Anatolian city-state Kanesh/Kultepe (Adams 1974; Curtin 1984; Veenhof 1972; Dercksen 1996; Orlin 1970). In addition, Larsen (1987) found a core-periphery approach is very useful when the scale of interaction is between wide areas, such as: Mesopotamia, Syria, Anatolia, Iranian highland and far-east Afghanistan.

This core-periphery interplay could be meaningful to identify different economic, social and political elements of other areas. For instance, Larsen (1987) argued that Old Assyrian textiles were an important product in the exchange with Anatolia for silver and gold, Afghanistan and Susa (Iran) for stones, and Maggan (Oman) for copper via Dilmun. On the other hand, Kohl (1987a,b) argued that Wallerstein's assumptions of core dominance, trade, and asymmetric exchange as prime movers would be problematic for the interpretation of social change and

interaction in the ancient world, particularly in western Asia. Thus, a modification is needed, in particular to address asymmetric exchange.

The World-System Theory does not address the multi-faceted, large-scale nature of interregional interaction between Mesopotamia and the rest of the Arabian Gulf region (Edens 1992). The archaeological and textual evidence supports the existence of a trade relationship in which Oman/Magan supplied Mesopotamia with copper in mid-third millennium BC. However, there is no evidence that Mesopotamia was a core that exercised monopolistic control over Oman or even exchange at large. Instead Oman was an independent entity that traded with both Mesopotamia and the Indus Valley. Therefore, Kohl (1987a) argued that Magan as a periphery was not passive and subject to Mesopotamia. Social, political and ideological factors should be taken into account and recognized as other mechanisms for trade (Edens 1992:121). Moreover, the archaeological evidence from the Gulf has shown that those who were considered peripheries, like Dilmun and Magan, traded prestige goods similar to the core Mesopotamia; inevitably, scholars had to deconstruct the core-controlled asymmetric exchange of the world system theory to explain the phenomena. Edens argued that it is difficult to define which materials are prestigious in the Gulf system because there was a switch in called-prestigious goods, particularly, copper and marine shell in the third and second millennium. This shift or decline in status of materials has led us to explore the role of agency, elites, and ideology. The value of material choices could be for enhancing the status and legitimize hierarchy, as gift exchange, or economic profit.

The obscurity or absence of a core in the Near East has caused theoretical problems for archaeologists. In the Gulf system, how can archaeologists determine which polity is a core when the exchange occurred between numerous small political entities in the south Persian Gulf, the



Indus Valley, and Afghanistan? Trying to apply the WST model to different entities across geographical zones has made it hard for scholars to identify and distinguish between the semi-periphery and periphery. The semi-periphery designation is very important in world system because it requires a middleman role in the interregional interaction. It is characterized by a combination of institutions and activities from the core and periphery. From archaeological evidence, it might be possible to determine whether a region was a transit or entrepôt point between two regions (e.g. core and core or core and periphery), but it is difficult to determine if it was a semi-peripheral zone if it shows no aspect of the core's institutions and activities.

This difficulty is exacerbated when there is more than one world-system in a particular geographic area. For instance, we assume that there was an Old World system and we also assume that we can separate the respective regions into different zones: Mesopotamia and the Indus Valley as the cores; Dilmun, Magan and the Persian plateau as semi-peripheries; and Qatar and United Arab of Emirates (UAE) as peripheries. However, it might not be possible to identify semi-peripheral regions if they exchanged with other peripheries to make a new world-system. This problem is still under debate in Arabian Gulf archaeology. For example, some archaeologists have shown that Failaka Island was a trading entrepôt and transit point for the flow of commodities such as copper, ivory and other metals from neighboring countries into the region (Weisgerber 1986; Potts 1986; Cleuziou 1986; Howard-Carter 1986). Based on WST category and research done, Failaka Island seems a semi-periphery since it mediated the interaction between the Indus Valley and Mesopotamia. However, the architectural features and other Bronze Age materials of Failaka do not support that it shared any institutional aspects with either Mesopotamia or the Indus Valley (Edens 1986). What designation should Failaka Island

have since it lacks the features to be a semi-periphery? The latter issues suggest a number of problems inherent to the world system's model and its processes.

Stein (1999, 2002) proposed the distance-parity and trade-diasporas models that undermined the notion of the core's dominance and power over the periphery because of distance. In the distance-parity model, Stein (1999) suggested that the core could not exercise hegemony over faraway regions. This distance-parity model allows scholars to explore the ability of the periphery to exercise symmetrical exchange and hegemonic power. Moreover, Stein (1999, 2002) suggested that trade-diasporas model supports the study of the role of material culture, agency, and social identity in the redevelopment of interregional interaction. The concept of trade-diaspora was developed by Abner Cohen (1969, 1971) in order to understand the social context and exchange between distinct Hausa traders and Yoruba host community in Nigeria and adjacent region of West Africa. Stein (1998) argued that the role of agency is crucial in network interaction even in peripheral zones and that individuals are not passive recipients of unidirectional control from the core. Stein (1999, 2002) proposed that the trade diaspora model could help unravel the organization of interregional interaction in fourth millennium BC colonial networks.

The trade-diaspora model can be applicable when there are communication and transportation difficulties between two social landscapes. Also, the trade diaspora can serve as an alternative when a centralized state provides ineffective economic or physical security to participants in far off regions. Thus, these states incorporate 'emissaries' as ethnic groups with the host communities to control commodities. During their stay in the host community, they might influence the host community by presenting new types of ceramics or architectural features. Stein (1999, 2001, 2002) found that Uruk ceramic forms were presented at Hacinebi;

furthermore, kiln wasters indicate that Uruk ceramic styles were manufactured on-site by ethnic groups but under the dominance of the local host community.

#### **4.4 Recent Models Applicable To the Future of the Arabian Gulf Research**

In general, my inquiry at Failaka Island would examine the nature of social interaction within the community and explore the scale of interregional interactions in Gulf exchange. The political economy theories would allow me to explore and focus on the role of administrative power and elites of Dilmun in Bahrain and Failaka Island during the second millennium BC. Its application would push the theoretical boundary for exploring sociopolitical and economic interaction in the Gulf network by re-defining the different scales of communications. For example, Dilmun stamp seals at Bronze Age sites on Failaka Island can be used as a line of evidence to discuss the standardization of seal and pottery production in Dilmun and the power of the material distribution in the Gulf. Various elements and symbols on Dilmun stamp seals (Howard-Carter 1972; Kjeurum 1983, 1986) attest to the presence of multiethnic population on the island around 2000 BC. Anatolian and Levant influential elements engraved on the stamp seals (i.e. acrobats, griffin heads, bull alters, etc.) allow us to examine the existence of various ethnic groups on the island who might have cooperated with island rulers to control the flow of commodities and share the profits. Combining stylistic interpretation of Dilmun stamp seals with quantitative data of chemical and mineral composition of ceramics may allow us to evaluate the effectiveness of the political economic theories for interpreting the multi-ethnic population of Failaka Island and the administration's power of the second millennium BC.

There is no evidence to support of any colonial activities in the Gulf during the first half of the second millennium BC as noted at a trading colony of Kanesh in Anatolia. The research

potential that the presence of foreign ceramics or raw materials on Failaka Island represents is exponential. The range of explanative possibilities of the socioeconomic interaction between foreign traders, administration and the local communities may: 1) Dilmun elites control mainland production and distribution of wares to satellites; 2) alternatively, Dilmun elites controlled only the mainland, not satellites; or 3) Dilmun craft specialists are independent of elites and there is no standardization of ceramic recipes.

The concept of “emulation” could be considered to identify the attempt of elites to adopt some elements of different groups into their own culture- to cope with cultural discontinuity. Based on the typological analysis and distribution of Edomite pottery in the Judean Negev in Israel, Thareani (2009) argued that the trade-diaspora model is valuable to the discussion of cultural orientation. The presence of tribal groups with an Edomite cultural orientation resided in the Judaeen Negev in the Iron Age. These tribal groups were active in the region and settled the urban centers to connect with Neo-Assyrian Empire and the South Arabia trade system. The stylistic repertoire suggests the Edomites desired to maintain their ethnic identity (Thareani 2009).

Edens (1987, 1994, 1999) introduced a modified version of Polanyi’s “port-of-trade” for the Late Bronze Age in Bahrain and Qatar. Port-of-trade was Polanyi’s concept (1963) to illuminate exchange economy between two independent societies, such as between market and non-market societies that have professional traders. Members of trading a powerful society can control this interaction by settling in another society for exchange economic purpose. Edens (1987, 1994) used an aspect of this concept to discuss the control of the flow of commodities and cultural identity between Qatar and Babylonian Kassite during the second half of second millennium trade. For instance, he argued that the relationship between Mesopotamian Kassite

and Qatar was based on trade-of-port exchange. The Kassite had a control on purple-dye production, processed from the shellfish *Thais*, for coloring textiles. The Kassite control on Bahrain was to insure the route of purple-dye from Dilmun to Mesopotamia, whether controlling private activities (sailors) or having institutional dominance. However, the Kassite pottery at Khor Ile-Sud in Qatar proposed such institutional context of a purple industry in the Gulf.

The exchange network with neighbors can further develop society as a result of the competition between powerful individuals who obtain prestigious goods for themselves and the necessities for commoners (Clark and Blake 1993). Moreover, not only are powerful individuals or aggrandizers important for promoting social and cultural change, but commoners who support the aggrandizers also enhance their positions by building networks to monumental structures (Pauketat 2000). This competition either within communities or between regions may have exercised that generate powers within the society. In order to general theoretical models, archaeologists have been utilizing various analytical instruments to better understating the inquiries that are related to the ceramic provenance, ancient technology, and movement of pottery. In the next chapter, I review the methodological background of using archaeometric analyses in the Near East and the advantage and disadvantages of each instrument in the ceramic studies.

## **CHAPTER FIVE: METHODOLOGICAL BACKGROUND OF ARCHAEOOMETRY IN THE NEAR EAST AND THE ARABIAN GULF**

### **5.1 Introduction**

Provenance studies are unique inquiries that draw relationships between the compositional characterization of raw materials for pottery (data) and other lines of evidence from the site (i.e. flora, fauna, ethno-historic information, etc.). Tykot (2003:63) wrote that several prerequisites were necessary in order to carry out a successful provenance study, such as: 1) the geological sources must be known for reference points; 2) the physical characterization analysis (e.g. density, color, mineralogical and chemical composition) and parameters must be based on these sources; 3) noted homogeneity of one or more properties with an individual source is very important; 4) the data obtained from the resources must be measurable and show statistically valid differences among parameters and; 5) the differences must be measurable when using analytical methods appropriate for archaeological artifacts. In addition to these prerequisites, the choice of the instrumentation is very important for provenance studies. In this chapter, I review the advantage and disadvantage of most used analytical instruments in the archaeological studies and the archaeometric approach in the Near East and adjacent regions.

Analytical instrumentation has increased in sensitivity and precision, and a wide range of mathematical and statistical software are now available to support meaningful, quantitative analysis (Tykot 2003). Archaeologists have a range of methods to choose from to determine the composition of pottery samples, such as: 1) destructive methods, like petrographic thin sections,

atomic absorption spectrometry (AAS) and inductively couple plasma (ICP); 2) to minimally destructive methods like such as neutron activation analysis (NAA), laser ablation inductively couples plasma inductively plasma (LA-ICP-MS) and X-ray fluorescence (XRF); 3) and completely non-destructive instruments, such as a portable X-ray fluorescence spectrometer (pXRF).

The effective use of these kinds of advanced instruments requires careful sample selection and preparation. For instance, samples must be powdered to ensure homogeneity for both XRF pellet and fusion and to put into a solution for AAS and ICP. With LA-ICP-MS, the sample can be analyzed in the laboratory in a solid form as long as it fits within the laser ablation chamber. The laser would typically remove only 1-2 mm in diameter leaving a tiny crater (Tykot 2003). A sample can be analyzed in a solid form via pXRF, if it can be transported to the instrument. A sample must be cut and affixed to a glass slide or ground to a uniform thickness for thin section analysis (Day et al. 1999; Herz and Garrison 1998; Rice 2005). Another consideration is the type of ceramic under scrutiny. Its surface characteristics and/or its bulk composition will help determine the instrumentation that can be best used. If the ceramic potsherds are coated with paint or glazed, NAA may be the most viable because the décor does not prevent accurate bulk composition. On the other hand, XRF and LA-ICP-MS are essentially for surface analysis (Tykot 2003); any coating on potsherds could affect the X-rays and/or lasered material as compared to the core of the sherd.

The choice of instrumentation is also based on the particular elemental signatures the researcher is trying to detect. A major element is defined as an element that occurs in the earth's crust, has a concentration greater than 1.0 wt percent, and is abundant as  $O^{2-}$ ,  $Si^{4+}$ , or  $Al^{3+}$  (Herz and Garrison 1998). They are found in compounds, like: silica ( $SiO_2$ ), titania ( $TiO_2$ ) alumina

(Al<sub>2</sub>O<sub>3</sub>), ferrous iron (FeO), magnesia (MgO), lime (CaO), soda (Na<sub>2</sub>O), potash (K<sub>2</sub>O), ferric iron (Fe<sub>2</sub>O<sub>3</sub>), water (H<sub>2</sub>O), and phosphorous pentoxide (P<sub>2</sub>O<sub>5</sub>). The minor elements are present from 1 percent to 0.01 percent and trace elements are present less than 0.01%. The trace elements (e.g. zirconium, strontium, manganese, rubidium, uranium, zinc, and thorium) are crucial to provenance studies and sourcing clay (Herz and Garrison 1998; Munita et al. 2001; Rotunno et al. 1997; Tykot 2002). They are not abundant in the earth's crust and can assist in the identification of the geological sources of raw materials, a 'fingerprint'. They are reported as elements in parts per million (ppm % or 0.01%). Whether the aim is to detect major, minor, or trace elements, it is important to consider if the technique is: 1- quantitative, such as wavelength dispersive XRF, NAA, ICP for determining the amount and proportion of chemical composition; or 2- qualitative such as XRD and thin petrographic thin section for identification the mineral composition and specimen. X-ray diffraction (XRD) also can be semi-quantitative technique because it can identify different mineral components and estimate their relative proportion. Surface-based techniques, like XRF, pXRF, LA-ICP-MS and proton-induced X-ray emission (PIXE) are good for determining major and some trace elements; while solution-based techniques, like NAA, are good for many trace elements (Tykot 2003). Other techniques measure limited number of trace elements, like ICP-OES and XRF (Ciprian Stremtan, personal communication 2011), or are best for very low abundance element like ICP-MS (Hatcher et al. 1994; Hoeck et al. 2009).

Each type of instrumentation has its own characteristics in terms of the precision and accuracy of measurements. The analytical precision is a measure of the reproducibility of an analysis, and is influenced by all aspects of sample preparation as well as the instrument's measurement conditions (Tykot 2003). Accuracy is a measure of the degree to which one's



measurement of recognized reference materials approximate accepted values (Williams 2003). Unlike analytical precision, one can improve accuracy of measurement by correcting or calibrating to the values of reference materials; thus, the closer the results are to the standards of known values, the more accurate the measurements are.

Specifically, in the context of my research aims, limitations include: 1- to use an analytical technique that is destructive or not given the nature of the samples and cultural affiliations; 2- the quantity of samples needed to obtain statistically valid measurements with the chosen instrumentation; 3- the cost of per sample for standards needed to calibrate the instrumentation; and 4- time constraints associated with the availability of the instrumentation.

## **5.2 Destructive versus non-Destructive: Strengths and Limitations**

I shall compare analytical methodologies using INAA, ICP, OES, AAS, XRF, XRD, petrographic thin sections and, pXRF, which have all been shown be effective in provenance studies for mineral characterization or chemical analyses of samples in the Near East (Herz and Garrison 1998; Comodi et al. 2004; Mirti et al. 2004; Munita et al. 2001; Rice 2005; Rotunno et al. 1997). Most of these are methods that take advantage of different portions of the electromagnetic spectrum (Rice 2005; Tykot 2003). These methods measure the intensities of specific wavelengths of the energy emitted by the sample. Peaks at certain wavelengths are characteristic of certain elements; the intensity or “area under the peak” is proportional to the amount of that element present in material analyzed (Rice 2005; Tykot 2003).

The basic premise for the ceramic provenance studies and compositional characterization is that the ancient potters select their raw materials, either clay or temper, from nearby sources and within a reasonable distance of the site of manufacture. Although firing alters the original

mineralogy of matrix, it will not affect the chemical composition of ceramics. Qualitative chemical data can differentiate ceramics groups with a statistic and/or typological validity (Blackman et al. 1989). Therefore, any appearance of chemically distinctive ceramic groups is usually attributed to trade and exchange and/or interaction with different production centers. The latter techniques have demonstrated their reliability in grouping ceramic types based on chemical and mineral composition. A common drawback of these instruments is that they require a destructive process for sample preparation to work. The samples from Kuwait and Bahrain had to be returned, precluding options of using any techniques other than a quantitative pXRF that I shall discuss it later.

INAA, or abbreviated NAA, is a widely used, gamma-ray spectrometry technique, known for high sensitivity, accuracy, and precision (Rice 2005; Tykot 2003). Its values lies in the simultaneous determination of numerous elements, particularly trace elements. INAA can be used to detect about 75 to 90 naturally occurring elements (Rice 2005). It can measure over 23 elements simultaneously (Day et al. 1999; Hughes et al. 1999, Blackman et al. 1989). INAA requires a source of thermal neutrons, such as an accelerator or nuclear reactor. Because of the heterogeneous nature of ceramics, a small sample for ceramics must be ground, and its surface must be removed (if glazed or painted) by drilling of the surface. Samples powders are placed in plastic or a glass vials, along with powdered standards for calibration, and these are placed into the reactor core. The nuclei of the atoms are excited by bombardment with neutrons at a controlled rate for a brief period (Rice 2005). This bombardment generates radioactive isotopes of the elements of interest that then decay, emitting gamma radiation, eventually forming stable isotopes. The rate of decay varies element and isotope. Day et al. (1999) demonstrated that some elements, called short-lived radionuclides (i.e. Sm, Lu, U, Yb, As, Sb, Ca, Na, La), can be

measured after a cooling period of 8 days, while three weeks required to determine the longer-lived radionuclides (i.e. Ce, Th, Cr, Hf, Tb, Sc, Rb, Fe, Ta, Co, Eu). The gamma ray energies (i.e., wavelengths) are particular to each formed nuclide. This energy is measured by either scintillation detectors or a Ge (Li) semiconductor in a gamma spectrometer apparatus. For the quantitative measure of the concentrations of various nuclides, it must compare the intensity of these gamma rays with those emitted by standard.

Advantages of INAA include the ability to detect more than sixty elements, including rare-earth elements, all at ultra-trace amounts, with 1-5% precision. Also, the sample size required can be very small; a piece of sherd 1 x 1 cm for powdering is enough (Day et al. 1999) and does not need further preparation; thus, it is considered a minimal destructive method. The method is completely automated and many samples and elements can be determined simultaneously taking into consideration those elements that have long half-lives and need more time for decay (Rice 2005). INAA can measure as low as parts per billion (ppb) and its neutrons and gamma rays can penetrate deeply to analyze the entire specimen (Rice 2005). The expense of this method is a deterrent for it can cost up to two hundred dollars per sample for a complete analysis (Rice 2005). Due to its cost, archaeologists using INAA have analyzed relatively few in their provenance studies, on average between 60-90 potsherds (Day et al. 1999; Hughes et al. 1999; Munita et al. 2001). This is a very low sample size for initiating a scientific study of pottery in any region which is recommended at least 300 samples for effective provenance study. The use of a seventy samples and each is cut to 1 X 1 cm sherd, to be representative of the ceramics on a regional scale will be problematic. Furthermore, the determination of on-lived radionuclides can take more than 3 weeks and then might extend the procedure of the analysis into many months (Day et al. 1999; Rice 2005). Finally, some elements can better be determined

by other methods. For example, XRF is more precise for determining Rb, Sr, Y, Nb, and Zr than INAA (Chen et al. 1999; Day et al. 1999; Hughes et al. 1999; Munita et al. 2001).

Like INAA's ability for trace elements, inductively coupled plasma mass spectrometry (ICP-MS) is another popular method used in provenance studies that can determine minor and trace elements. Using a laser ablation (LA) system for sample introduction increases the potential value for this technique because it can analyze a solid sample without any solution and destruction. However, the highest sensitivity analyses normally require a powdered sample (Speakman and Neff 2005). More than 60 elements, mostly all trace elements, can be determined at ppm levels either by as ICP-MS or LA-ICP-MS modes (Herz and Garrison 2005). Using LA, the analyzed area is usually about 1000 x 1000 microns and less than 30 microns deep, and the ablated materials are transported from the laser cell to the plasma via an argon carrier gas (Speakman and Neff 2005). LA technology is a good technique for determining bulk compositional data for solid samples leaving a very tiny damaged spot- it is a minimally destructive method. It has been shown to yield reliable results for grouping various ceramic types from Bronze Age sites in Romania (Hoeck et al. 2009) and Iron Age red figure pottery from Italy (Mirti et al. 2004).

The advantage of ICP-MS in general is its ability to collect precise and accurate data for many elements in the periodic table above mass 86, but also some lower atomic mass species. Another advantage is that LA-ICP-MS can provide data with a range of low parts-per-million (ppm) to parts-per-trillion (ppt) (Speakman and Neff 2005). Significantly, LA-ICP-MS can be used like an electron microprobe to target specific components, and can obtain data from temper grains and/or clay matrix area. The LA technology does a minimal amount of damage to the sample and with computer software integrated with LA, many spots and lines or raster patterns

can be detected over the area of interest. ICP-MS has several advantages including rapid analytical time, low cost per sample, and its ability to perform different types of ceramic analysis (bulk, surface, microprobe) (Speakman and Neff 2005).

ICP-MS detection limits are lower than INAA, XRF, and PIXE for many species. However, applying the minimally destructive approach of using LA is restricted by the size of analyzed sherds. Some ceramic potsherds are too large to fit in an ablation chamber, the case with most samples from Kuwait and Bahrain. Ceramics are heterogeneous and choosing to sample only a small piece would affect both sample integrity and potentially yield a non-representative measurement, unlike obsidian, which is usually compositionally homogenous. The location of the sample taken with the laser cell, surface typography, texture of sample and laser energy all should be taken into consideration while using ICP, to avoid any side effect of intensity of signal (Speakman and Neff 2005). There is a problem inherent to ICP-MS that is called spectral interferences. In LA-ICP-MS technology, the spectra are obtained from the isobaric matrix that represents elements themselves and/or their oxides. In contrast, ICP-MS, because of the argon gas plasma, produces argides and hydrides and other matrix-induced spectral interferences that affect analysis (Speakman and Neff 2005). Thus, there is a complicated procedure and it needs calibration to separate the spectral interferences and to ensure the accuracy of quantified data.

Inductively coupled plasma optical emission spectrometry (ICP-OES) is a quantitative spectroscopic technique. By exciting the outer electrons of atoms with the thermal energy of the plasma (at 10000K), the atoms release light energy as they return to their ground states. This energy is emitted in defined light wavelengths characteristic of particular elements excited. Also, the quartz prism or diffraction grating disperses the light of different wavelengths. The

quantitative analysis then is obtained from the intensity of light emitted (Pollard et al. 2007; Rice 2005). This method is destructive because it requires the dissolution of 5-100 mg of powdered sample for analysis. ICP-OES can measure 20-30 elements in major, minor, and trace quantities, down to 100 ppm with accuracy of >5-10 percent (Rice 2005). ICP-OES has the ability to detect many elements present in the sample, and can analyze approximately 20 elements simultaneously. ICP-OES can easily be employed to any part of the pottery body regardless of decor because it requires a small amount to be removed from the sample. This technique is readily available and rapid and the instrument has good reproducibility. However, some concerns on the difficulty of excitation of atoms that probably affect the precision and accuracy as well as minimum detectable level (Pollard et al. 2007; Rice 2005).

Atomic absorption spectroscopy (AAS) detects the elements by the absorption of light of an atomized sample in a flame. The technique is destructive and requires the sample to be dissolved in a solution prior to analysis, usually 10 mg to 1 g is fine for ceramic and geological samples for minor and trace elements. The method is a sequential technique, meaning it identifies one element at a time. The atoms of an element absorb a portion of light from the source, a cathode lamp, and the detector can determine the concentration of one element by the amount of light absorbed (Pollard et al. 2007; Rice 2005). To determine the second element, the light must be changed and standards and samples must be reanalyzed. AAS is inexpensive, simple to use, and is able to determine approximately fifty minor and trace elements. It's highly sensitive, particularly if it determines a few elements with high carefully prepared standards (Rice 2005). The disadvantage of AAS is the chemical and spectral interference. It can be expected to have overlap from the emission lines of two elements in the sample, spectral interference. Chemical interference is more common and problematic due ionization. Once an

element is ionized, it will have a different electronic energy level, due to the high temperature flames; thus, the absorption spectrum changes (Pollard et al. 2007). It is not efficient for detection multiple elements. Also, contamination is more possible due to diluting the sample in acid because this will interfere with the absorption of the element in the flame, causing inaccurate quantitative results (Rice 2005).

XRF has been employed for chemical classification and ceramic provenance studies. Its affordability and availability has made it a more viable technique than others. A specimen in XRF is irradiated with primary X-rays from an X-ray tube or from radioactive sources. These X-rays, in turn, emit secondary fluorescent X-rays with characteristic wavelength of the elements in the specimen (Herz and Garrison 1998; Rice 2005; Shackley 2011). The secondary X-rays are produced when X-rays from the source displace electrons from inner orbits of the constituent atoms and the energy levels are filled with electrons from the outer level. Then, these secondary x-rays are examined with a spectrometer either through diffraction by a crystal (wavelength-dispersive XRF) or with a semiconductor detector and multichannel analyzer (energy-dispersive XRF), representing the intensity of X-rays. Each of these x-rays or peaks represent individual elements that have a series of wavelengths; also the X-ray intensities are used to obtain quantitative determination by using a series of correction and calibration (Herz and Garrison 1998; Rice 2005; Shackley 2011). XRF is considered non-destructive if there is a small sample that can be inserted into chamber rather than the removal of a small piece. However, the homogeneity of ceramic samples usually has to be tested. Therefore, it is common for sample preparation to be done by grinding and powdering the sample (200 mg to 2 g) into a fine powder and creating pellets, making the method completely destructive.

XRF offers several advantages. It is useful to determine 80 elements in major, minor, and trace quantities at the same time, particularly powerful for those above atomic number 12, in ppm. (Herz and Garrison 2005; Rice 1998; Shackley 2011). Those with an atomic number of 7 or 9 are difficult to be determined because they have low energies (i.e. low, long wavelength) and their x rays might be absorbed by air (Herz and Garrison 1998; Rice 2005). It is useful to analyze some elements that cannot be obtained by INAA such as magnesium and titanium and it is more precise for potassium and calcium (Rice 2005). XRF is also another widely available and relatively low in cost. In addition, to its minimal preparation, XRF spectrometry enables to one to determine chemical compositions in a minute or less and for trace elements, at ppm concentrations, in 3-10 minutes (Shackley 2011). The principal disadvantage of XRF is its sensitivity to the thickness and shape of the ceramic sample, affecting the quantitative measurement. However, it can be corrected by increasing the sensitivity of modern detectors and a shift to a digital connection between the instrument and the computer as well as software updates (Shackley 2011). It is difficult for XRF to analyze some rare earth elements and those with low atomic numbers, unlike INAA. If the ceramics are glazed or painted, XRF could be used to analyze the surface and determine glaze, slip or paint. For clay sourcing it is better to remove the coating surface or choose unpainted or unglazed samples for nondestructive analysis. Finally, if archaeologists employ the non-destructive XRF technique, they have to take into consideration that the beam width of XRF can analyze an area 1 cm in diameter; thus, while one can avoid a diagnostic feature of a sample, this area might not be representative.

All analytical methods discussed above are used to identify the chemical elements and their components in the ceramics. Their principal function is to present quantitative characterization of each element in the ceramic samples for determining their sources. However,



these methods still have a major roadblock and that is their difficulty to distinguish between composition from clay paste and temper. Thus, numerous studies have been employing other techniques such as petrographic thin sections and XRD to identify mineral components and focus on inclusions from the clay and temper (Comodi et al. 2004; Day et al. 1999; Unlu 2011).

Petrographic thin sections are one of the most useful techniques for identifying minerals and inclusions in the clay and temper. It provides information about the size, shape, and orientation of minerals and their alteration resulted from firing. Sample preparation for this method requires removing a 1-3 cm section from the pottery, making it as destructive method; also, the slice of sherd should be impregnated with epoxy resin to consolidate its friable or porous texture (Rice 2005; Herz and Garrison 1998). Then, the sherd must be affixed to a glass slide and the section should be ground on a lap with finer abrasives to a thickness of 0.03 mm and coverslip of glass. The appropriate thickness is determined by observed birefringence colors, such as: a quartz grain is a pale yellow; and feldspar is gray or white under cross-polarized light (Rice 2005). This technique can be used to analyze non-plastic inclusions, often coarse fraction, that naturally occur in clay or are added intentionally, such as mineral inclusions, rock fragments, organics (e.g. shell, bones, etc.) and grog (i.e. crushed fragments of fired ceramics). A polarizing microscope is employed to identify minerals that are subjected to transmitted light. There are two polarizing filters, called nicols, in the polarizing microscope that restrict the vibrational direction of light passing through them into minerals in order to characterize the minerals. The section sits on rotating stage than can be turned 360° such that the orientation of the polarized relative to the sample is changed. The sample can be seen through objective lenses that magnify (e.g. 25X, 40X + a 10X ocular) and resolve the image (Rice 2005).

When plane polarized light passes through crystals, it can divide into two wavefronts with different velocities and different vibrational orientation. Minerals that split incident light into two wavefront are called A-isotropic minerals. Most minerals are anisotropic, and they each have different properties. Anisotropic minerals may be identified using only plan-polarized light (i.e. uncrossed nicols) based on their pleochroic color. Some minerals can be simply identified through their colors, such as biotite mica, feldspar, quartz, hornblende, augite, and tourmaline (Rice 2005).

The advantage of thin-section petrography is its ability to identify mineral constituents and their abundance and alteration while providing useful qualitative information about manufacturing technology and provenance data. To obtain quantitative data, Felix Chayes (1956) has developed a method (i.e. modal analysis) to obtain the percentage of inclusion by counting the fragments in thin sections or measuring the relative areas underlain by each of the mineral species. A more recent method is to draw linear transects to count the grains between “ribbons” or lines (Rice 2005:381). The disadvantage is that petrographic analysis cannot determine the extreme fine-grained nature of clays (Rapp and Hill 2006:239) and thus it is more useful for low-fired ceramics. It is destructive and a sample cannot be reused after impregnation with epoxy resin. Based on a personal experience, it is difficult to carry out petrographic thin-section analysis without prior training and knowledge. Identifying minerals requires a minimal experience about various minerals (i.e. color, refractive index, etc.) and physical properties (i.e. crystalline structures, density, cleavage, fracture, hardness, streak, and luster). In addition to the description, texture, and fabric structure of a sample, the analyst should also have knowledge of chemical weathering and the secondary minerals that are formed in soil or sediments as a result

of geochemical processes (i.e. hydration and oxidation) and thermal stress (i.e. firing, volcanism, etc.).

In addition to petrographic thin sectioning, XRD is another method of identification minerals (qualitative) by their crystalline structure. Each mineral has a distinctive chemical structure and composition, a unique atomic arrangement (Herz and Garrison 1998; Rice 2005). X-rays in XRD are produced when electrons bombard a target or specimen and in turn the specimen reflects or diffracts the X-rays that are picked up by a detector producing an X-ray intensity or peak. Ceramic samples are to be finely ground and powdered into 20 mg for XRD analysis. The sample is placed on a glass slide and inserted in the diffractometer chamber for rotating between an angle and the detector. This method measures line position or angle of diffraction and intensity, making it more useful for quantitative determination.

The advantage of XRD is its ability to identify minerals in high-fired pottery such as mullite, cristobalite and tridymite that forms at temperature over 900°C (Herz and Garrison 1998; Rice 2005). The disadvantage of XRD includes that it is oriented for discerning the presence of a small number of minerals in clay or fired ceramics. Moreover, XRD is a semi-quantitative because many corrective measures prevent direct relations between line intensity or peak area and quantity (Rice 2005). Unlike petrographic analysis ability to determine inclusion size and alteration, XRD cannot provide information about whether minerals occurred naturally or added as temper nor any data on mineral size, shape, etc.

In addition to all techniques discussed above, there are various analytical techniques that are less employed on ceramic clay sourcing. Proton-induced X-ray emission analysis (PIXE) is used based on proton excitation rather than X-ray photons. The advantages of this technique are that the analyst can: 1) use the proton beam for analyzing down at least 1mm diameter, 2) use

powdered or solid samples as XRF, and 3) rely on the high sensitivity and accuracy in obtaining major and trace constituents (Rice 2005). The disadvantage of PIXE is the high cost of the equipment, which can restrict its availability. Scanning electron microscope (SEM) is employed to generate qualitative and semi-quantitative chemical and mineral data; particularly, identifying structural change in ceramic fabrics and imaging microstructural and textural characteristics of ceramic pastes (Herz and Garrison 1998; Rice 2005). The electron microprobe has more accuracy than SEM for quantitative determination of bulk composition of a clay matrix and its textural structure. Combining SEM and XRF principles, electron microprobe can detect major and minor elements, and focus on tiny areas or points (i.e. inclusion, glaze, pigment, etc.). This technique is destructive requires that a small sample must be removed, impregnated with a resin, and then polished to have a flat surface for beam penetration (Rice 2005). It is not a fully automated instrument and one needs training in its use, such as using the integrated software and hardware to select image or area of points for taking picture. The analyst using this electron microscopic technique must be knowledgeable of surface features (i.e. topography, composition, morphology, etc.) before focusing the beam on a small area of interest. The latter techniques require training in the use of the instrumentation and related computer software as well as a forehand knowledge of some basic geology.

### **5.3 Archaeometry in the Near East and Adjacent Regions**

In general, provenance studies in Mediterranean have been accomplished using different techniques, such as archaeometric methods, petrographic thin analysis, INAA, XRF and LA-ICP-MS, XRF. There are few studies that employed archaeometric methods on ceramics in the Arabian Gulf (Blackman et al. 1989; Grave et al. 1996; Méry et al. 2012; Mynors 1983). Also,

the work of Sophie Méry and her colleagues (1989, 1991a,b, 1995, 2000, 2007, 2012) concentrates on using petrographic thin sectioning technique to characterize ceramics and identify fabric types from fourth and third millennium BC sites in Oman and the United Arab Emirates (UAE). Méry demonstrated a connection by comparing Mesopotamian and Makran fabrics from Mesopotamia, Iran and the Gulf. The petrographic analyses confirmed the presence of Mesopotamian vessels in Eastern Arabia, implying its participation in the larger trade network that included Iran and Indus Valley. There is only one study that used petrographic analysis on Dilmun ceramics (n= 8), from Dilmun sites in Bahrain, along with samples from UAE and the Mesopotamian site, Larsa (Méry et al. 1998). The paste compositions results show the relation between Larsa and UAE samples with a reference to a Dilmun ceramic group from Bahrain. Adjacent to the Gulf, the mineralogical database obtained from petrographic analysis was useful to quantify the geological component of Early Bronze Age ceramics from Lebanon (Badreshany and Genz 2009). Even though it was difficult to identify the exact clay source due to the availability of quartz, micritic, limestone and calcite in the Lebanese mountains, petrography was able to clarify firing temperature pottery production in the Early Bronze Age.

A few studies focused on the provenance of raw materials of ceramic types in the Arabian Gulf using INAA. Along with petrographic thin section, INAA was employed to examine the origin of foreign jars from the Oman Peninsula and to determine a zone of production in Indus Valley (i.e. Harappa vs. Mohenjo-Daro) and Iran (Blackman et al. 1989; Méry and Blackman 1995, 1999). Studies have shown the success of INAA studies of ancient and Islamic ceramics from Mesopotamia. Mynors' study (1983) involved the analysis of third millennium BC ceramics from different locations in Iraq and two sites in the UAE. The results obtained by INAA and petrography showed that there was a chemically distinct ceramic group from each

site. Hallett's study (1999) successfully used INAA and petrographic analysis to characterize Sasanian and Islamic glazed ceramics from the Abbasid period. Hallett also demonstrated that the latter were complementary techniques. Hallett (1999) identified compositional differences of ceramics and different clay sources in Mesopotamia and Iran. Furthermore, Hill et al. (2004) used INAA for differentiating ceramic pastes along with LA-ICP-MS as a microprobe analytical technique for identifying the constituents of the ceramic glaze. Stein's works (1999, 2002) supports the application of INAA for identifying the chemical composition of sealing clays from the late Chalcolithic Age at the Hacinebi Tepe site, South Anatolia. The results supported the Mesopotamian origin of some seals, illustrating the presence of standardized Uruk administrative authority in Anatolia; also, implying communication with other colonies in Northern Mesopotamia and Syria.

Along with petrographic thin section study, chemical analysis using XRF has been employed to obtain quantitative data about Bronze Age ceramics from Oman, UAE and Mesopotamia as well as to provide proper elements for discrimination (Méry and Schneider 1996, 2001). The latter studies' results (high calcium vs. low manganese) revealed that chemical outliers have different petrographic composition, indicating the Southern Mesopotamian origin. XRF has been the only analytical method used in Kuwait (Pollard 1987) to identify the chemical components of a few glass, faience and glazed pottery. The results revealed that the glazed pottery has an extraordinary alkaline earth ration in the Bronze Age material and it is particular to that temporal period on the site.

Scholars have demonstrated the value of these analytical methods and how much information can be gleaned from the data produced. These provenance studies have contributed to the discussion about the production and distribution of artifacts and their association with the

socio-cultural interactions between different regions. For my research, non-destructive portable X-ray fluorescence (pXRF) can be employed to determine the chemical components of Early Bronze Age ceramics from Kuwait. Energy-dispersive portable XRF works similar to regular X-ray fluorescence. Though it is considered a new technique in archaeological studies, pXRF has been employed in the last decade for identification and characterization of ancient metals (Ferretti and Moiola 1998), gold and silver jewelry (Karydas et al. 2004), and obsidian tools (Craig et al. 2007; Shackley 2005; Tykot 2002). A few studies have employed pXRF on ceramics and clay tables (Ashkanani and Tykot 2013; Goren et al. 2010; Liritzis et al. 2002; Papadopoulou et al. 2006; Papageorgiou and Liritzis 2007; Speakman et al. 2011; Tykot et al. 2013). Archaeologists have employed INAA, ICP, and laboratory XRF for ceramics to address trade and exchange issues. There is a reluctance to use this handheld instrument for provenance studies on ceramics because of the inherent complexity of ceramics as well as the sensitivity and precision of the commercial instrument. However, our pilot study demonstrated that this non-destructive technique, pXRF, is able to distinguish a group of Bronze Age ceramic potsherds among Failaka Island sites collection (Ashkanani and Tykot 2013). The results showed that there were a few potsherds that had different chemical components and had an associated with the Ur III tradition and possibly Iranian-Indo border according to their surface treatment (i.e. color and hardness).

## **CHAPTER SIX: METHODOLOGY AND SAMPLES**

### **6.1 Introduction**

This study is designed to determine the scale production of Barbar pottery, to locate Barbar production centers, and to explore the circulation of nonlocal pottery during the early second millennium at Bronze Age sites. The study included ceramic sherds from Bronze Age sites on Failaka Island in Kuwait, Bahrain, Indus Valley, particularly from Harappa main center in Pakistan, and Iran. Collecting samples from the aforementioned regions is necessary because of their widespread circulation throughout the Arabian Gulf region during the Bronze Age. They might be beneficial as a reference group for nonlocal sherds that may be found within Dilmun sites.

To determine the possibility of homogeneity in Barbar ceramic recipes, technology, and production, each sample group from each Failaka phase is compared to a selected sample group from Bahrain, which its periods are parallel and contemporary with Failaka periods in the second millennium. For instance, some samples were taken from the Barbar Temple IIb phase that is contemporary and parallel with the earliest phase in Failaka, Period1 (ca. 1950 BC). Also, samples from Northeast Temple, period APR-ARU were also selected because they are contemporary and parallel with Failaka F3 samples. The aim is to determine any recipe change synchronically and diachronically within Dilmun sites and differences between Failaka Dilmun ceramics versus Dilmun of Bahrain. By comparing each phase, the research can shed light on the



development of local type pottery in Dilmun and possibly identifying any kind of attached and independent specialists, controlling of raw materials and ceramic manufacturing.

This sampling strategy is known as judgmental sampling. It is necessary because of the research questions that aim to compare between certain pottery types in each chronological phases, the nature of the analytical technique, the quality of the samples selected, and the parameters of the curation of the samples. For clay and temper material sourcing it is better to remove the coating surface or choose unpainted or unglazed samples for pXRF analysis. Due to the sensitivity of the instrument to the sample surface and to obtain possible bulk minerals, surfaces of glazed and painted ceramic potsherds were excluded. Moreover, cooking ceramic potsherds that are diagnostic with a black-carbonized inner and/or outer surface were also excluded. Thus a purposeful sampling strategy is important to obtain all Barbar pottery that has no paint or categorized as cooking pots. Also, it was used to exclude any painted ceramic sherds from Iran and the Indus Valley to obtain better chemical composition of the clay and temper materials.

In judgmental methodology, samples are not representative of the whole and it is a non-probabilistic form of sampling; it is a grab and purposeful sampling (Green 2007:4). Archaeologically, the selection of sample is based on looking over a range of ceramic sherds in the population and then deciding to include certain ceramic sherds and exclude others (Drennan 1966:88) due to the nature of analytical instrument, and museum curation and permission.

The latter sampling strategy was employed to answer the posed research questions and to test the reliability of pXRF as the main analytical tool for analyzing archaeological ceramics from the Arabian Gulf and the adjacent regions. Alongside the chemical analyses with pXRF, I included in this study an analysis of a subset of Bronze Age sherds using petrographic thin-

section analysis. The results from the thin-sectioning analyses served as test for reliability of the data obtained by pXRF and determine the raw materials used in ceramic production and technology. The sample strategy and preparation and data processing are provided for both analyses. Finally, the commonly used statistical analysis approach for provenance study is also provided in this chapter, applied to the pXRF analysis to identify compositional grouping of Dilmun versus nonlocal ceramics, which might help in addressing trade and exchange with long distance regions and control of raw materials and standardization and distribution of utilitarian vessels in Dilmun as well.

## **6.2 Sampling Strategy and Materials**

The samples analyzed in this study consists of 304 ceramic sherds and clays from various types of early Bronze Age pottery on Failaka Island in Kuwait, Bahrain, Eastern Province in Saudi Arabia, Deh Luran plain and Susiana plain in Iran, and Harappa in Pakistan (Table 6.1). The sampling strategy is based on using different ceramic traditions- Barbar versus Mesopotamian traditions- from various sites as a reference groups. Each reference group selected is well identified and its provenance is known or sherds are found in kilns. For instance, Dilmun sherds from Barbar Temple and Qala'at sites are collected as a reference group of Bahrain clay while Harappan sherds come from the pottery kilns at Mound E in the main Harappa center in Pakistan.

There are two criteria for using ceramic samples instead of clay or geological samples as a reference group, the pottery kiln strategy and the 'Criterion of Abundance'. The first criterion is to have ceramic samples from a well-documented archaeological context; particularly from pottery kilns, the immediate site of ceramic production. For example, the pottery kiln criterion

has been applied in Crete and Mycenaean ceramic studies. It helped to distinguish major sites of consumers and redistributors of ceramics from production centers (Catling et al. 1963; Day and Kiriati 1999; Jones 1986). The second criterion is the “Criterion of Abundance” in which ceramics are assigned to the production centers based on their abundance as particular types within the archaeological sites, units, or workshops (Tite 1972; 1999). For instance, a production center of Barbar styled ceramics could be identified based on their concentration at their site. The potters would have presumably used specific clay to produce compositionally similar ceramic products (Hein et al. 1999; Mommsen and Sjöberg 2007).

The samples used in this study have been selected based on the typological standards of Højlund (1986, 1987, 1994a). The samples from two main Bronze Age sites on Failaka Island and Bahrain as well as those that are curated at the Moesgaard Museum in Denmark, have been well documented and identified stratigraphically and chronologically. The Moesgaard collections are considered references for each phase and site in Failaka Island and Bahrain. Based on the multivariate analyses, 10-15 sample sherds were selected from the Moesgaard collection representing early phases on Failaka Island and Bahrain sites and any early-phase outliers. To determine the recipe of the pottery, the pXRF instrument measures non-destructively the inner, outer and edge as well to determine the chemical composition of the clay and inclusions.

Based on a typological analysis, Failaka Bronze Age ceramics have been divided into two groups; Barbar-pottery tradition and Mesopotamian-pottery tradition; a few samples are unknown (Højlund 1987). Various rim-sherds, bases, body-sherds, lower body parts and decorated sherds (ridged) were selected and those representing jars, bowls, plates, and ovoid vessels. Some of the sherds cannot be assigned to specific category due to the sherd size. Ceramic potsherds from F3 and F6 sites on Failaka Island and all Bahrain sites were collected

the Moesgaard Museum in Denmark, as they are curated from the 1950-60s excavations in Bahrain and Kuwait and are well documented, unlike the potsherds stored in Kuwait, for which only the field number is written on the boxes (Højlund 1987:8). Only Al-Khidr ceramic sherds

Table 6.1 Summary of all sample materials from Kuwait, Bahrain, KSA, Iran and Pakistan.

Site	Structure	Region	Sample Size	Phase
Tell F6	The Palace	Failaka Island, Kuwait	16	Period 1
Tell F6	Trench E	Failaka Island, Kuwait	35	Period 1
Tell F6	Mesopotamian House	Failaka Island, Kuwait	18	Pre-Period 1
Tell F3		Failaka Island, Kuwait	11	Period 2
Tell F3		Failaka Island, Kuwait	6	Period 3A
Tell F3		Failaka Island, Kuwait	12	Period 3B
Alkhidr		Failaka Island, Kuwait	91	Period 2A-2B
Barbar	Temple II	Bahrain	10	Period IIb
Barbar	NE Temple	Bahrain	11	APR-ARU
Qala'at		Bahrain	9	Period IIF
Qala'at		Bahrain	5	Period IIIa
Tepe Farukhabad		Deh Luran plain, Iran	5	Sukkalmahhu Elamite
Susiana plain		Iran	8	Sukkalmahhu Elamite
Susiana plain		Iran	5	Early Middle Elamite
Susiana plain		Iran	11	Late Simashki Elamite
North Susiana		Iran	7	Proto Elamite
Harappa	Mound E	Pakistan	30	Period 3B
Harappa	Mound AB	Pakistan	3	Period Cemetery H
Clay	Al-Sabiya & Kazma	Kuwait	2	
Clay	F6 (the Temple)	Failaka Island, Kuwait	2	
Clay	Al-Ali	Bahrain	2	
Clay		Eastern Province, KSA	5	
			Total 304	

were collected from Kuwait, particularly, from the Archaeological Mission Center and Storage on Failaka Island. This collection is curated on the Island under the supervision of the National Museum of Kuwait and was a subject of study by the Kuwaiti-Slovak Archaeological Mission.

The Bronze Age ceramics from F3 and F6 on Failaka Island were collected from excavation layers horizontally, about 30 cm thick and rarely thicker than 40-60 cm (Højlund 1987:7). Based on typological development that is linked to the various occupation phases, ceramics from Failaka Bronze Age, particularly from F3 and F6, have been grouped into 7 periods (Figure 6.1) extending from 2000 to 1200 B.C: period 1, 2A, 2B, 3A, 3B, 4A, and 4B (Højlund 1987:107). In this research, I will focus on the Bronze Age ceramics from Failaka Island dating to the first half of the second millennium, the Dilmun/Pre-Kassite period 1- 3A (2000-1550 BC.). In particular, I shed light on the first quarter of the second millennium (2000 – 1800 BC) to examine the homogeneity of ceramic recipes on Failaka Island, Kuwait. This period is a time of Dilmun flourishing and developing city as Qala'at and unique social structure like the royal mounds and the temples. Thus, archaeological samples from Kuwait and Bahrain that cover the first quarter of the second millennium BC will be a subject of pXRF and thin section analyses to determine the chemical components and possible ceramic groups.

A total of 66 potsherds were taken from tell F6 in the southwest of Failaka, which consists of three sites: the Palace, Trench E, and the Temple. Among 66 sherds, a total of 16 were taken from the palace-like feature known as the Governor's Palace. The samples were taken from the earliest phase known as Failaka Period 1, ca. 1950 BC, recovered during the 1962-62 excavations. Period 1 sherds represent ware-type A, B and C as described in chapter 2. Tell F6, consisting of the Governor's Palace and the Temple, is considered a Dilmun site based on architecture and remnants similar to contemporary Dilmun sites in the Kingdom of Bahrain.

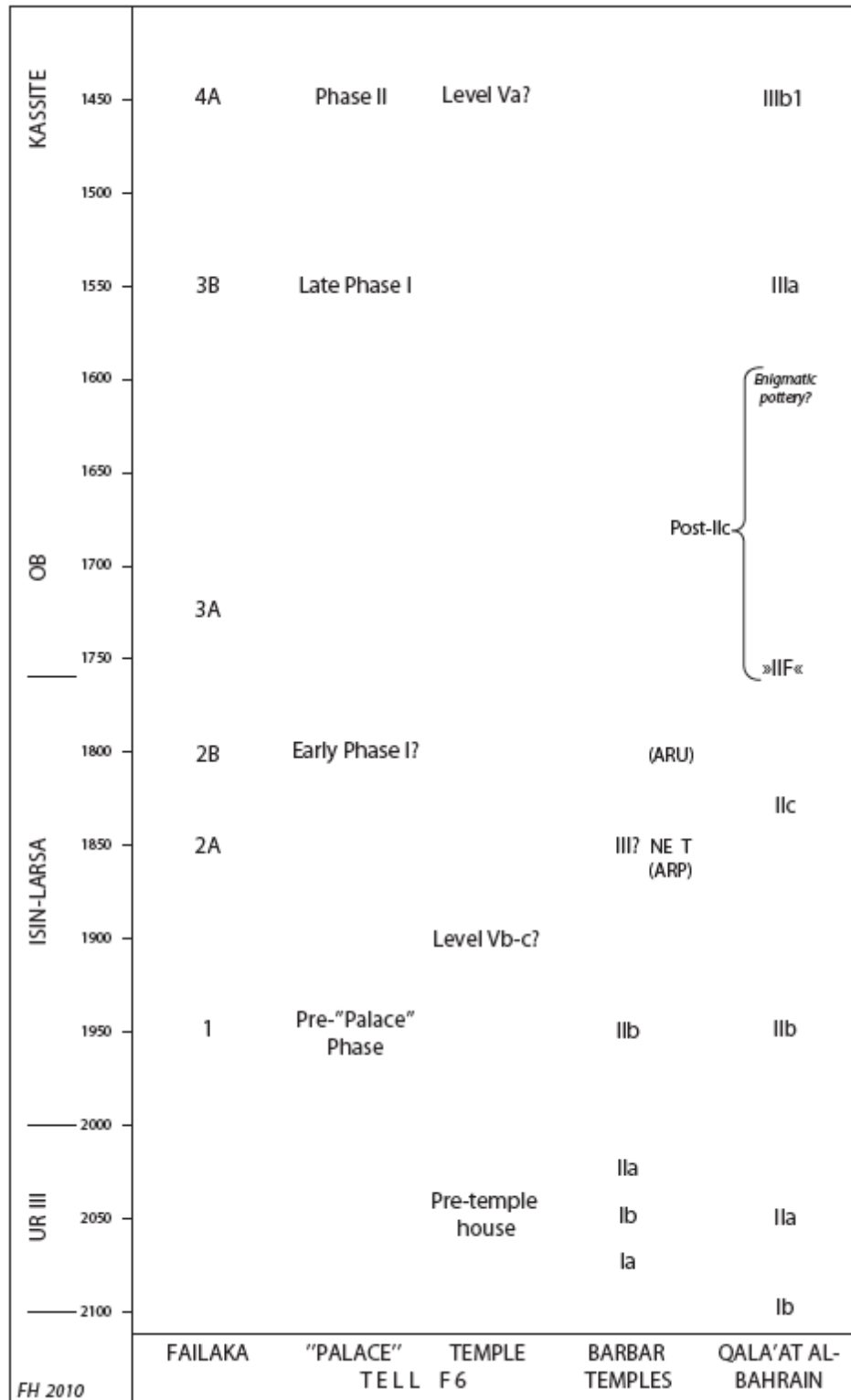


Figure 6.1. Chronological Chart of the late third-second millennium BC in Failaka Island and Bahrain sites (Højlund 2012).

A total of 35 samples were taken from a new trench (Trench E), which lies between the Governor's Palace and the Temple in Tell F6. This trench was excavated during the Kuwaiti-Danish mission of 2009 to determine if there was a connection between the palace and the temple (Højlund 2012). All ceramic potsherds selected for from this trench Tell F6 are affiliated typologically with the Dilmun tradition and parallel to phase Failaka Period 1 in the Palace, with a few unknown and unusual types found at the site.

Moving to later phases, a total of 29 samples were taken from tell F3 in the southwest of Failaka Island. These samples were taken from the later phases in the same tell that is not apparent at F6. The samples represent phases - Period 2A-B (circa 1850 to 1730 BC.), Period 3A (circa 1730-1550 BC.), and Pro-Dilmun Period 3B (1550-1450 BC.). Their ware-type varies from type A-E and G as well with a noticeable increase in Barbar wheel-made and nonlocal potsherds.

A total of 91 ceramic samples came from Al-Khidr on Failaka Island in Kuwait. Al-Khidr samples are the largest collection in this research. They were collected during the Kuwait-Slovak Archaeological Mission's excavation from 2004-2009 and are curated in the storing house in the center of archaeological missions on Failaka Island. Approximately, 1,139 fragments of pottery were collected, registered, and was a subject of preliminarily typological classification and relative dating (Benediková 2010). Pottery types are assigned to three pottery traditions, such as: the Barbar red-ridged jars, bowls, spouted vessels and plates, Mesopotamian-tradition pottery, and Eastern-tradition fragments. Most of the Barbar pottery, particularly from seasons 2004 and 2006, was dated to Failaka period 2A-2B (1850 – 1730 BC), which Flemming Højlund combined them later as Period 2 (Højlund, personal communication 2010). More Barbar pottery was also selected from 2008 season as the earlier seasons represent uppermost horizon excavation. Pottery

from later periods (e.g. Kassite) also occurred in the assemblage. Only pottery from two seasons was a subject for a close classification and grouping. They were categorized into seven ware groups. Only three of the seven ware-types were noticed in this research collection; red/orange coarse ware, yellow coarse ware, and red/yellow fine ware (Benediková 2010). None typical Barbar pottery sherds (e.g. greenish/gray colors) were also collected to represent nonlocal and possibly imitated sherds. Those usually associated with straw marks on the ceramic surface. Their color is grayish to pale green. Despite Al-Khidr pottery can be identified as after and before Failaka classical phase (Dilmun period 2A-2B), the studying of Al-Khidr pottery and relating the stratigraphic layers to known relative Dilmun chronology are still incomplete and need detailed analysis (Benediková 2010).

Parallel to Failaka later phases Period 2A-B and 3A, a total of 11 samples were taken from the Northeast Temple that is lying 30 m northeast of the Barbar Temple. The NE Temple was almost completely demolished and pottery assemblages were found in the plastered central platform (Højlund 2003:249). A large assemblage of Barbar pottery was found outside of this platform and are parallel to Failaka tell F3 Period 2A (NE Temple 517.ARP) and Failaka tell F3 Period 2B (NE Temple 517.ARU). In general, pottery collection from NE Temple is only related to those two phases (ARP phase ~1850 – 1800 BC and ARU phase ~1800-1730 BC.), with no evidence of early or late pottery (Højlund 2003:249). All the potsherds are Barbar tradition vessels. They are grouped into reddish and greenish hand-made sherds representing ware-type A and B, and increasingly type C.

A total of 9 samples came from Qala'at site and were taken from phase IIF that is parallel to phase - Failaka Period 2B and 3A (~ 1860 – 1550 BC.). This phase began between Failaka Period 2B and 3A and its samples are diagnostic with increasing Barbar tradition yellow-reddish



and green-grayish wheel-made wares. They are all C ware-type, except one A ware-type storage ceramic sherd.

Only 5 samples came from Qala'at, phase Period IIIa, as contemporary and parallel to Failaka later phase Period 3B (1550 – 1450 BC.). They are grouped into hand and wheel-made Barbar and wheel-made Mesopotamian tradition pottery, representing only ware-type C and E. The Barbar vessel pottery represents red and greenish ware-type C sherds and white-yellowish ware-type E for Mesopotamian samples.

In addition to the Bahrain reference group, samples were taken from well-known traditions to represent Mesopotamia, Iran, and Harappa to examine the success of using nonlocal ceramics as reference groups. For creating a ceramic group of Mesopotamia, 19 sherds were selected from the Mesopotamian House trench that has been recently discovered in tell F6 on Failaka Island. They were unearthed from a trench during 2008-09 Kuwait-Danish excavation at the Temple in Tell F6. The Mesopotamian sherds were found in a stone-built corner of a house that is layered under Dilmun temple structure and date back to Ur III, ca. 2100 BC (Højlund 2012). The trench was embedded with fragments of bitumen, quantities of animal bones and Mesopotamian pottery (Højlund 2012). Among numerous sherds uncovered. Only 19 rim and body sherds were selected for the research to represent red/green hand and wheel-made Mesopotamian tradition. Among 19, two uncommon sherds (Barbar and Achaemenid) were also included for further analysis and possibly identifying their production center.

A total of 35 of Iranian ceramic sherds came from three different locations; Tepe Farrukhabad in Deh Luran Plain, Susiana Plain, and North Susiana in Khuzestan province (Figure 6.2). They are curated at the Museum of Anthropology at the University of Michigan, Ann Arbor, under the supervision of Professor Henry Wright. Deh Luran is located in the

northwest of Susiana plain as a key position connection Elamites in southwest of Iran with the Upper Mesopotamia beginning from the third millennium BC and Susa to western Anatolia during Achaemenid period in the mid of first millennium BC (Wright and Neely 2010). Its geographic location, as a small trough between the first fold of Zagros and the Jebel Hamrin with two rivers (the Mehmeh and Dawairiji) cut the plain, provides environmental variation for human to exploit the rich resources (Wright and Neely 2010:2). The plain was the area of interest for many archaeologists to evaluate hypotheses about the development of irrigation system, change of subsistence strategy (e.g. Kent Flannery, Frank Hole), trade and political development (e.g. Henry Wright and James Neely) to better understanding the settlement sequence and development over millennia.



Figure 6.2 Map of southwestern Mesopotamian, the upper Arabian Gulf and southwestern Iran showing Deh Luran and Susiana plains in Khuzestan, Iran.

Tepe Farrukhabad in the Deh Luran plain, in which the sample came from, was excavated by Henry Wright the University of Michigan Museum of Anthropology in 1968 to test a hypothesis about the effect of the increase of the population and conflict over land and the decrease of land quality on one hand, and the increase of population as a motivator of increasing interregional exchange on the other hand; it is an effort to examine the process of town growth and administrative development (Wright 1981). The Elamite ceramics from 1986 excavation of Tepe Farrukhabad were well stratified and cover three main phases which correspond to Simashki (ca. 2100-1900 BC.), Sukkalmahhu (ca. 1900-1600 BC.) and the Transitional phase, known also as the Early Middle Elamite (1600-1400/1300 BC.) which indicates the political control of Susiana rulers on satellite villages in Deh Luran region (Carter and Wright 2010:11-22; Henry Wright personal communication). Three buff brown and cream-colored goblet sherds, one greenish jar sherd and one medium-coarse buff-slipped brown jar sherd were selected from the analysis to represent a variety of Sukkalamahhu phase pottery.

Among 6 samples from Tepe Farrukhabad collection, one sherd has been excluded, as its outer and inner surfaces are painted, while 2 samples have been analyzed only from the inner sides due to the erosion and non-flat outer surface. They are dated to Sukkalmahhu Elamite phase (1900-1600 BC.) and represent white-creamy slip goblets and greenish jars.

In addition to Deh Luran plain samples, a total of 30 samples came from Susiana Plain and its northern portion and were taken from a surface collection from south modern cities, Dezful and Shush (ancient Susa). They are divided chronologically into three periods based on their typology; Late Simashki Elamite (2000-1900 BC.), Sukkalmahhu Elamite (1900-1600 BC), and “transitional” Early Middle Elamite (1600-1400 BC.). These 30 ceramic sherds are divided geographically into two parts; a surface collection from Susiana plain in Khuzestan with

assigned letter KH and numbers (KH-32, 37, 57, and 1400). Their major colors are greenish for the jars, and reddish-brown to gray for goblets (Henry Wright, personal communication). The other surface collection part came from north Susiana plain (KH-42 and 49). The Susiana plain is situated to the southeast of Deh Luran plain, in the modern-day Khuzestan province. This plain is one of the most productive agricultural plains in Iran as it is situated between the Karun and the Karkheh rivers. The lower Susiana plain is considered as an extension of the Mesopotamian plain as it consists of flat alluvial land with two major rivers such as the Dez, Sia Mansur and Karkheh rivers (Alizadeh 2008). Numerous archaeological missions have excavated the Susiana plain more than one hundred years (e.g. Rawlinson's 1839, Loftus 1857) to explore early villages and their development over time within this plain, settlement pattern and evidence of political centralization (Hole 1987:29-39). Among 30 Iranian sherds, 7 samples were taken from North Susiana plain, particularly from two sites, KS-42, which ceramic sherds date to Proto-Elamite (3350-3100 BC.) and Early Dynastic period (2900-2300 BC.), and KS-49, which ceramic sherds date to Early Dynastic period (2900-2300 BC.). John Aden surveyed the latter in 1977 along with other sites to locate Susa III period pottery (early third millennium BC. or late Uruk period), pre-dating our sherd samples. The KS-49 samples are two flakey reddish-brown jar rim sherds (sample nos. 15773 and 15774) with reddish brown slip dark red and dark grits and one buff brown goblet rim (no. 15772) yellow slip on medium to fine red grit). The French Archaeological Delegation in Iran surveyed the KS-42 site and the two brown ceramic samples (brown jar rim) were taken from this survey (Steve and Gasche 1971) and are curated at the Museum of Anthropology at the University of Michigan, Ann Arbor, under the supervision of Professor Henry Wright.

A total of 33 Indus valley ceramic sherds came the from University of Wisconsin-Madison collection as a referenced group of Harappa and the Indus Valley clay. They are found in the main Harappa site in Pakistan. A total of 30 sherds were taken from Mound E and 3 samples came from Mound AB (Figure 6.3). The Mound E samples are dated to period 3B (2450-2200 BC.) and a few samples from later periods, Harappa 3C (2200-1900 BC) and the Transitional Phase Harappa Period 4 (1900-1700 BC) (Meadow and Kenoyer 2005:207; Kenoyer, personal communication). The ceramic sherds represent a variety of fine grit, hard clay brown-reddish sherds of rims and body jars with a few examples of yellow-cream slipped outer surfaces. George F. Dales (University of California, Berkeley) and Jonathan Mark Kenoyer (University of Wisconsin, Madison) carried out the Mound E excavations during the three season 1986-1988 excavations in Harappa in Pakistan. Mound E and AB were two of the major areas of excavation to focus on Harappa cemetery, botanical materials, and craft activities from Early to Mature and Late Harappa period (Dales and Kenoyer 1991).

The Mound E collections are divided into two groups, the kiln (Lot 776) and outside kiln collection (Lot 772). The kiln for pottery manufacture was located on the northwestern edge of mound E (Figure 6.4) which also had nearby evidence for domestic structures (mud brick and brick platform) in addition to other craft activities such as copper smelting, agate bead manufacture, stone tool manufacture and shell working (Dale and Kenoyer 1990:75). The kiln is dated on the basis of radiocarbon samples taken from inside and outside the mouth of the kiln as well as comparative pottery analysis to around 2450-2200 BC., which corresponds to Harappa Period 3B (Meadow and Kenoyer 2005, Dales and Kenoyer 1990, 1991). Among 33 sample sherds from Mound E, 16 ceramic sherds were taken from inside the kiln and date to period Harappa 3B (2450 – 2200 BC.). A total of 10 samples came from outside of the kiln (Lot 772)

but in direct association with the pottery production from the kiln. The majority of the samples are reddish with red slip and black lines. The samples from outside the kiln are brown reddish jar sherds and some coated with a black slip. Also, a selection of 4 samples came from different lots on Mound E representing a later period (Harappa Period 3C, 2200-1900 BC.). They are reddish sherds with various exterior surface treatments such as unslipped, black slipped and ridged Harappan cooking pots.

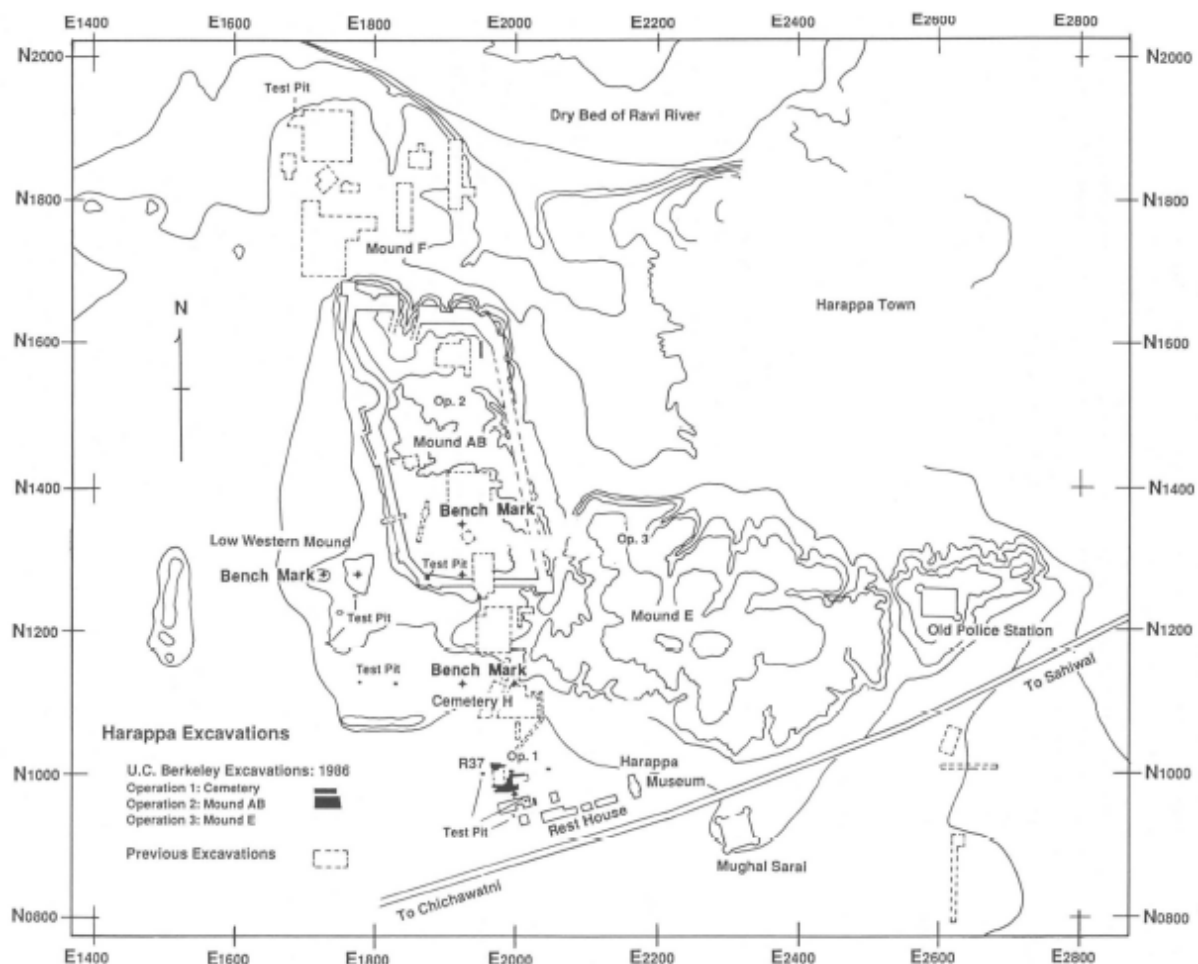


Figure 6.3 Map of settlements in Harappa showing Mound E and AB. Note the kiln area within Mound E (Dales and Kenoyer 1991).

Finally a selection of three samples came from Mound AB in Harappa, Pakistan, to represent the Late Harappan phase, also known by Indus Valley archaeologists as Cemetery H period 1900-1700 BC.). Mound AB is situated in the northwestern of Mound E and west of Harappa town. The pottery comes from the upper most surface of the Mound AB and are from disturbed contexts associated with domestic structures and craft activities of the Late Harappan period (Kenoyer personal communication 2013). Three sherd samples were selected from 1995 excavation at this mound and date to Late Harappa phase (Cemetery H period). They are two red painted jar sherds and one thin cooking pot sherd. The outer of painted sherds were excluded for pXRF analysis. A collection of the Cemetery H pottery was also found on the surface of the northwestern Mound E and in the excavation as well (Dales and Kenoyer 1990:138).

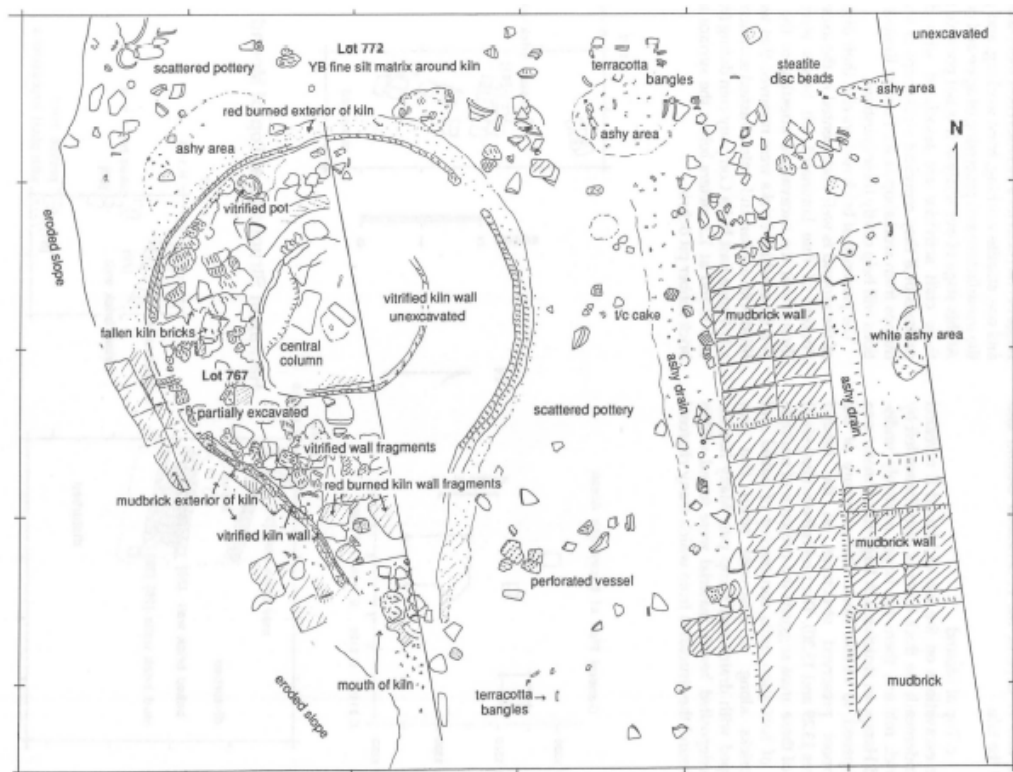


Figure 6.4 Plan of kiln area in Mound E, Harappa (Dales and Kenoyer 1991). Ceramic sherds were taken from outside the kiln and inside the kiln (circular wall).

The aim of selecting samples from various archaeological sites representing different geological parts of sociopolitical entities that participated in the Bronze Age trade and interaction is to overcome the lack of geological background of archaeologists and the procedures of obtaining geological samples. This research can provide more insight about how those reference groups from Iran and the Indus Valley are useful for fingerprinting nonlocal ceramic samples that are expected in this study. It helps in the future research to suggest obtaining or avoiding samples from these particular sites.

### **6.3 Analytical Method: Portable X-ray Fluorescence (pXRF)**

#### **6.3.1 Sampling Exclusions and Limitations**

For this research, the 2008 MURR calibration, which was originally designed by Robert Speakman and Michael Glascock for obsidian and other silicate materials, was conducted on the raw data obtained from pXRF at the Archaeological Science Laboratory at the University of South Florida. Speakman and Glascock began in 2006 using empirical calibration based on obsidian references to calibrate an ElvaX XRF and then developed it for the Bruker pXRF, along with an obsidian “green” filter, to be used since 2008 (Speakman and Shackley 2013). Thus, the data obtained by pXRF in this study is valid for the purpose of the current study, and may be re-calibrated in the future with other software for comparison with other studies. The matrix effect in pXRF is expected when dealing with the calibrated values. It requires standards of similar major element composition to produce accurate values, which has not been well developed for the pXRF yet. Therefore, the obsidian calibration is used for ceramics that are silicon-based.

Also, the small size of the X-ray window of pXRF (about 3 x 5 mm diameter) is another issue of poor representativeness and the effect of the grain size. Because the diameter of the



pXRF beam width does not represent a point analysis, but rather an average of a micron-scale area, it is not possible to identify a small component (matrix vs. clasts) unlike electron microprobe or LA-ICP-MS. Therefore, we analyzed multiple points in a single sample to ensure the ‘representativeness’ and homogeneity. The analysis was designed to run pXRF multiple points similar to Chayes (1956) modal analysis for thin section analysis in which variant shots are pointed along the length and width of the potsherd and then one can calculate the average percentage of different elements. It can be also analyzed by a traditional method that measures the percentage of variant runs along a set of lines. However, following the Chayes method or a set of lines presents some difficulty in this study due to the sensitivity of the pXRF to non-flat surface. Thus, it is a challenge to set a line on each surface avoiding any apparent inclusion or décor. Due to this sensitivity and to obtain possible bulk minerals, surfaces of glazed and painted ceramic potsherds were excluded. Moreover, cooking ceramic potsherds that are diagnostic with a black-carbonized inner and/or outer surface were also excluded.

Because there is some concern about analyzing a sample that does not have a smooth flat surface, affecting the actual X-ray angle, the sherd’s spot of X-ray exposure has been carefully selected, avoiding a non-flat area and visual temper inclusions. The inner and outer surfaces of the samples were analyzed and the edges as well for thick samples to overcome the potentially poor representativeness of non-homogenized samples and to ensure that the results are consistent (Figure 6.5). The multiple shots within the whole sample using pXRF were also performed recently for sourcing Bronze Age clay cuneiform tablets from Hattuša, Turkey, and el Amarna, Egypt (Goren et al. 2011), and in other parts of the world (e.g. Aimers et al. 2012; Tykot et al. 2013).

There was a concern that the slip material differs from the inner clay surface. For instance, the ovoid red slip vessel that was found in Madinat Hamad tumulus and dates to Early Dilmun (2000-1800 BC.), shows the reddish wine-colored slip was obtained from a red pigment. This reddish pigment is obtained from red ochre that probably originated from Iranian coastal islands (Lombard 1999:56-59). This type of vessel is imported either from Mesopotamian or the Oman peninsula and defined as a burial-offering vessel. This concern drew the attention to exclude the slipped outer surface of Dilmun sherds from pXRF analysis as no research has been done on characterization the slip of Barbar pottery. A total of 17 ceramic sherds were selected to examine the homogeneity of the outer slipped and non-slipped surface compared with the inner surface for sherds from Al-Khidr and the Palace from Failaka Island and from North Susiana in Iran and Mound E in Harappa. Among the selected 17 samples, a total of 5 samples were also selected to examine the homogeneity of non-slipped samples. The Bahrain sherds were excluded here due to the small size that makes it unable to run multiple shots and test positions within a pottery sherd.

For example, a test was run on sample no. 14232 for which its outer surface has incomplete black painted lines. A bivariate plot shows its outer surface does not overlap with the inner surface due to a much lower Y concentration than the inner surface (Figure 6.6A). The Rb vs. Zr plot also confirms that sample 14232 outer surface has a much higher Zr concentration than the inner surface (Figure 6.6B), making it impossible to obtain the average chemical composition for representing the whole sherd. This supports the prerequisites to be taken to perform pXRF, which is to eliminate any painted surface from the analysis. The heterogeneity of sample 14243 also confirms the importance of excluding the cooking pot or dark surfaces from the analysis, as noticed in the outer part of sample 14243. Overall, there is congruity between

inner and outer surfaces including the Iranian samples (15570, 15574), which make it appropriate to obtain the average of the measurement at different positions as the data value for each sample. It is difficult to conclude without using other analytical methods (e.g. SEM) that the slip clay is similar to the body clay. However, it seems by comparing the elemental composition of the slip outer surface with the inner surface of the sherd that the slip material does not differ from the body clay; it suggests that the slip clay possibly was a refined version of the body clay (Tite 1999:359). It is recommended that a future study run a combination of quantitative, qualitative and structural analyses (e.g. XRD, SEM, LA-ICP-MS) to examine the polishing surface and the slip materials of Barbar pottery and understanding the surface treatments and the application of slip materials.

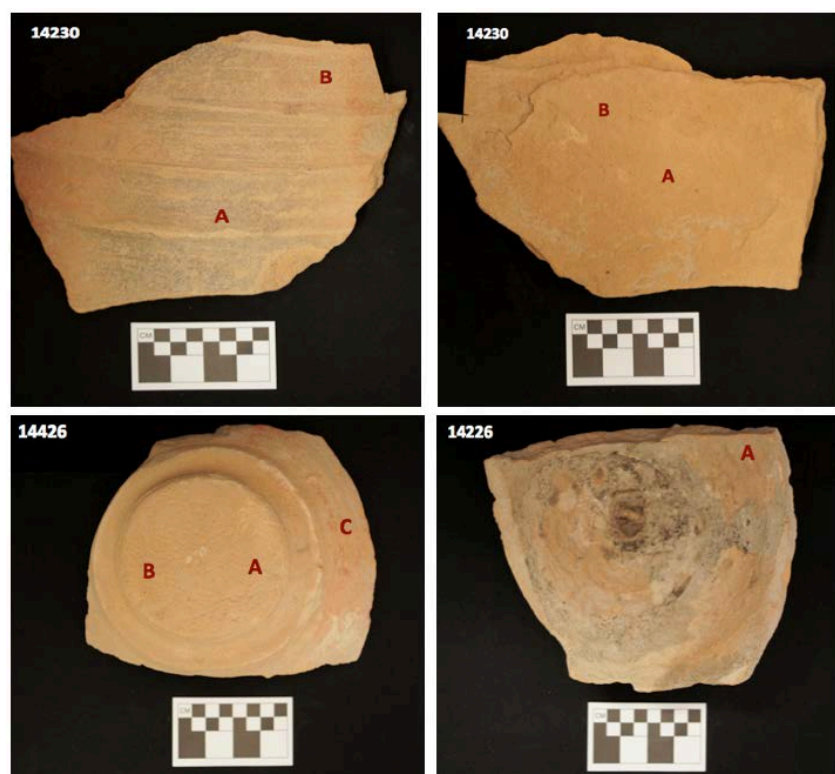


Figure 6.5 Selected spots (A, B & C) within each ceramic sherd for pXRF avoiding non-flat area. The slipped outer was selected to examine its homogeneity with the inner surface (Photo by Hasan Ashkanani).

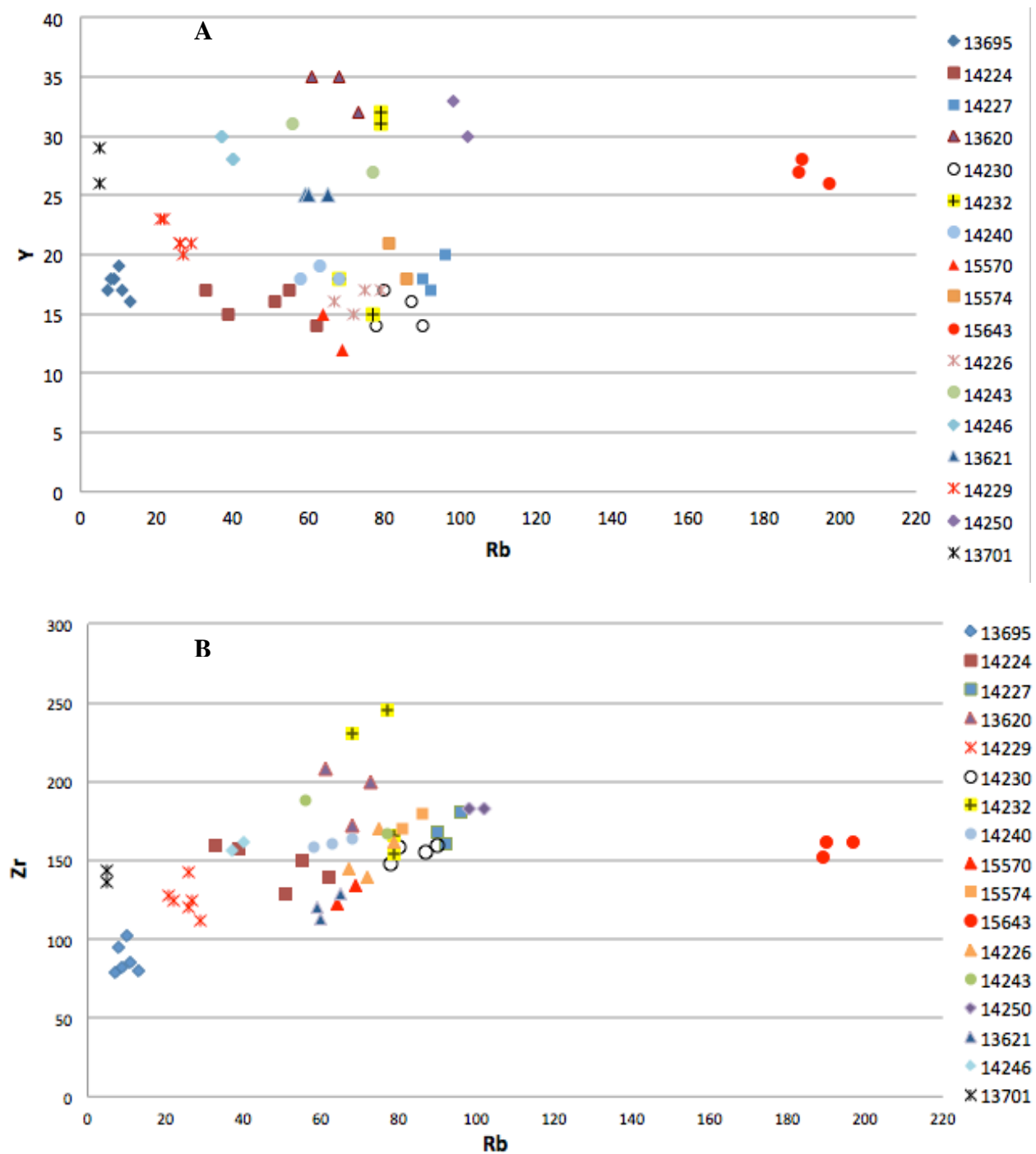


Figure 6.6 Biplot of Rb vs. Y (A) for ceramic data collected using pXRF for multiple shoots within each sample. The Rb vs. Z (B) confirms the outer surface of 14232 due to paint and 14243 due to darker spot as an indicator of cooking process.

### 6.3.2 Error Testing

In order to validate the results of the pXRF, a total of 13 ceramic sherds were selected for comparison with chemical composition results of ICP-MS analysis. Trace element chemical analyses were carried out using the facilities of the University of South Florida's Center for Geochemical Analysis with the assistance of a Ph.D. candidate, Ciprian Stremtan. In order to remove soil and dust particles, the samples were sonicated in ultra-pure DI water and rinsed thoroughly. After complete drying in a low-temperature drying oven, the samples were crushed to <200 mesh using an agate mortar and pestle.

Sample powders were digested following the typical  $\text{LiBO}_2$  fluxed fusion methodologies (modified from Kelley et al. 2003) to ensure complete digestion of resistant accessory phases (i.e., zircon) present in the raw material. Flux and sample, with a 4:1 ratio (total of ~ 1.0 g) were thoroughly mixed in a graphite crucible and fused in a muffle furnace at  $1055^\circ\text{C}$  for a minimum of 15 min. The fusion beads were then dissolved in 50 ml of 2%  $\text{HNO}_3$  solution spiked with 1 ppm Ge as an internal standard, and 1000 ppm Li was added as a peak enhancer to minimize matrix and background effects. Sample solutions were diluted a second step to 10,000:1 for major element measurements. For the low abundance trace element and rare earth element (REE) analyses, solutions were diluted to 1000:1 with 2%  $\text{HNO}_3$  spiked with 10 ppb In as an internal standard. Major oxides and selected trace elements (Sr, Rb, and Zr) were analyzed via direct current plasma optical emission spectrometry (DCP-OES) while trace element measurements were carried out on a quadrupole ICP-MS.

The calibration of the ICP-MS and DCP is a two-fold process. First, all measured solutions were spiked with Ge (for DCP) and In (for ICP-MS). These 2 elements are used as internal standards such that one has at least 1 or 2 elements with a known concentration in the

solution to be measured for ceramic samples. Standard reference materials that mimic best their geochemical compositions have been used. The following standards have been used: SGR-1 (Green River Shale - a USGS standard), SDO-1 (Devonian Ohio Shale - also a USGS standard), JA-2 (Japanese Andesite - a Geological Survey of Japan standard), JR-1 (Japanese Rhyolite - also a Geological Survey of Japan standard), and G-2 (Rhode Island granite – a USGS standard). DCP detection limits vary by element. Typically they vary from  $\pm \mu\text{g/l}$  for alkali metals such as K and Rb, to  $\pm 0.0001 \mu\text{g/l}$  for the most sensitive species (Sr, Ba, Be). The instrument is an FISIONS Spectra Span 7 DC Plasma Atomic Emission Spectrometer. All sample solutions are spiked with  $>1000 \text{ ppm Li}$  to produce a high positive optical emission matrix, which is done in lieu of background correction.

Compositional data for all elements measured by pXRF and ICP-MS are presented in Table 6.2. The accuracy and precision of the measurements for three samples carried out is generally less than 5% (Stremtan et al. 2014). The dataset for three samples yielded by means of ICP-MS is consistent with the results from the composition obtained using pXRF (Stremtan et al. 2014). As shown in Figure 6.7, selected elements measured both by ICP-MS and pXRF correlate rather well, with the exception of Sr.

Because Sr has partition coefficients larger than 1 in plagioclase and alkali feldspars from intermediate to acidic igneous rocks (i.e., granitoids), but smaller than 1 in most clay minerals (Nielsen)(Nielsen)(GERM 2011), the results yielded by pXRF have to be carefully interpreted as representative for the bulk composition of the artifact, especially in samples showing large plagioclase and alkali feldspar crystalloclasts. The other 10 samples also show similar results for the consistency between pXRF and ICP-MS analyses particularly for Rb, Y and Nb (Figure 6.8). However, the Zr and Sr concentrations of the 10 samples show more variation than the first three

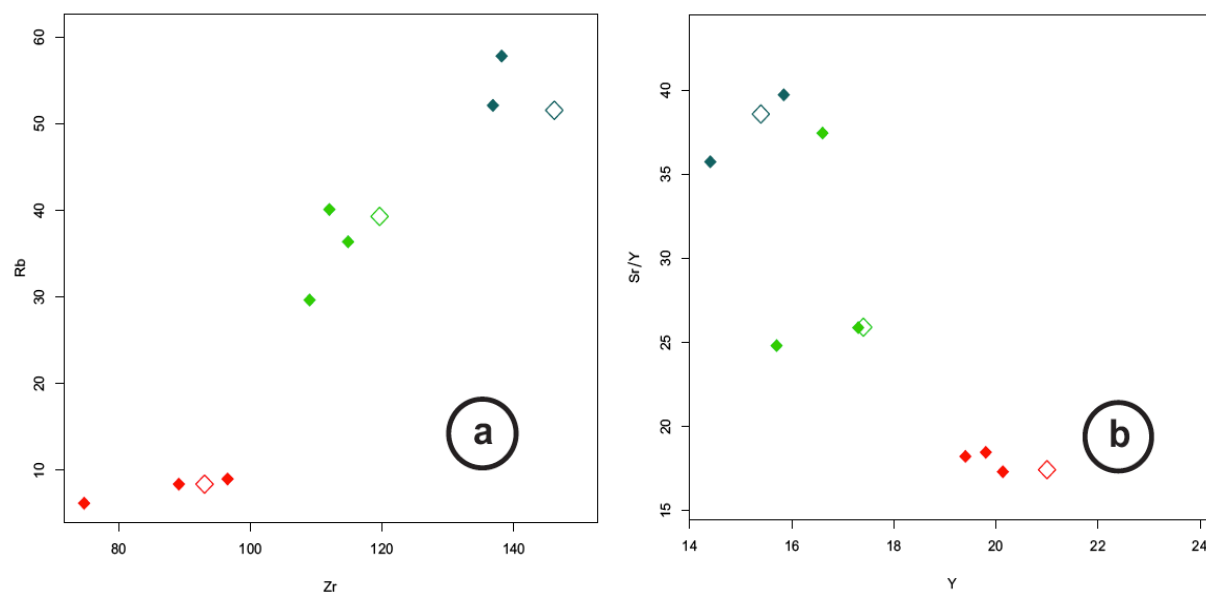


Figure 6.7 Selected elemental plots for three Dilmun ceramic samples from Kuwait. Open diamonds are samples analyzed using ICP-MS and filled diamonds are ceramic samples analyzed through multiple shoots by pXRF (Stremtan et al. 2014).

Table 6.2 Concentration of ICP-MS and pXRF for 13 selected ceramic samples.

	ICP-MS							pXRF						
Sample	Ba	Th	Rb	Sr	Y	Zr	Nb	Ba	Th	Rb	Sr	Y	Zr	Nb
<b>13634</b>	390	18	79	93	35	314	14	1756	6	79	483	30	112	7
<b>13677</b>	314	12	92	250	21	152	14	1401	6	78	255	30	135	7
<b>13683</b>	351	14	114	80	30	276	13	1983	4	51	764	28	123	4
<b>14231</b>	216	6	50	74	14	114	6	2535	4	28	876	32	153	5
<b>14235</b>	466	10	68	447	27	241	11	2953	5	52	1473	25	154	1
<b>14266</b>	460	13	87	200	30	244	13	2074	5	40	712	27	137	5
<b>14267</b>	478	12	73	277	27	241	13	3128	6	78	1042	28	163	6
<b>14268</b>	495	11	87	249	31	267	13	2829	6	66	783	31	167	8
<b>14294</b>	376	10	80	234	29	237	11	2357	6	71	884	28	158	6
<b>14295</b>	548	13	86	215	31	278	13	2411	6	54	1045	28	161	7
<b>13695</b>	87	7	8	373	24	105	12	1778	4	8	346	19	87	7
<b>13696</b>	144	7	54	451	22	142	13	2141	4	38	486	17	146	7
<b>13701</b>	136	7	50	438	21	150	12	1959	4	23	416	18	116	7
<b>Mean</b>	343	11	71	260	26	212	12	2254	5	51	736	26	139	6
<b>STD</b>	153	3	26	135	6	70	2	509	1	23	340	5	24	2

samples. The Pearson correlation results show that the pXRF and ICP-MS for the elements range from high to low correlations (Table 6.3). They show that Th is highly correlated while Ba, Rb,

Y and Nb are moderately correlated. They also show that Zr has low correlation while Sr has no linear correlation. The significance value reflects the same results as all trace elements have a significance value less than .05, except Sr, which means there is a statistically significant correlation between the pXRF and ICP-MS data. The possible variation in the results can be due to the heterogeneity of samples (i.e. mineral phases that are the main reservoirs for Zr and Sr are unequally disseminated throughout the sample), inclusions in the sample or due to the actual measuring of small areas bombarded by X-rays that yield less amounts of elements.

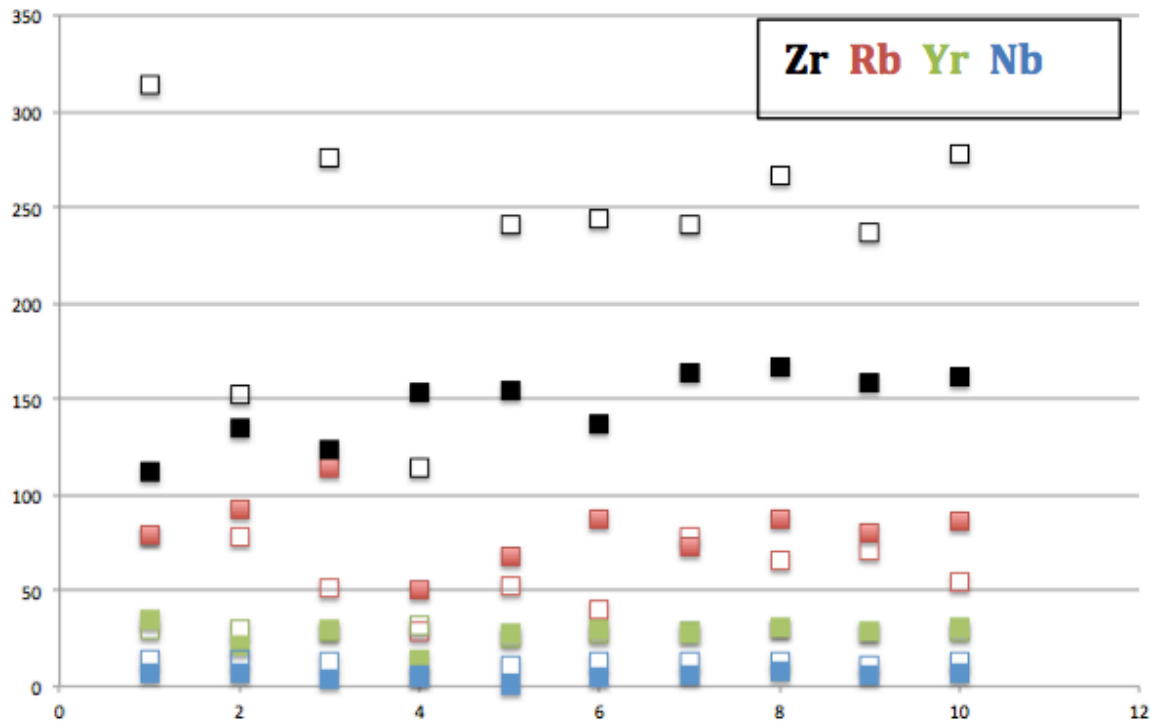


Figure 6.8 Selected elemental plots for 10 ceramic samples. Open squares are samples analyzed using pXRF and filled squares are samples analyzed by ICP-MS.



Table 6.3 Pearson correlation between ICP-MS and pXRF.

	<b>Correlation Coefficient (<i>r</i>)</b>	<b>Sig.</b>
Ba	0.542	0.037
Th	0.730	0.002
Rb	0.567	0.028
Sr	0.087	0.758
Y	0.665	0.007
Zr	0.464	0.081
Nb	0.599	0.018

When ICP-MS is used, the mineral constituents will be completely dissolved, and the resulting solution is homogenized, thus having a more realistic representation of the actual composition. The other possible issue is related to ICP standard materials used to compare against unknown samples, e.g. the Dilmun ceramic sherds. Based on the standards used, Ba measured by ICP is not very reliable, as most of the standards were low in this particular element. Ba and Sr are also rather easily re-mobilized during alteration and could be incompatible for comparison. The high value of Ba in the calibration MURR 2008 in pXRF is also due to the effect by Ti, whose Ka peak overlaps with the Ba La peak, thus are much higher than those from ICP-MS (Robert Tykot, personal communication 2014). The variability of such elements as Zr also may reflect higher analytical error that is inherent in ICP and heterogeneity in the ceramic samples measured by pXRF. The concentration of Th obtained by pXRF is relatively low due to the ability of pXRF to accurately measure low ppm Th (Speakman et al. 2011:3493).

There is some difference between the two analytical techniques, because some elements (Th, Y, Rb and Nb) are better for a comparison. To evaluate this disparity between the ICP and pXRF datasets, bivariate plots derived from principal components analysis (PCA) of the elements in common to both pXRF and ICP datasets (Rb, Zr, Y, Nb) were used to calculate the

covariance matrix and loading of each element as variables on to the matrix (Figure 6.9). The datasets were transformed into logarithms to standardize the data. In general, these figures illustrate the elements can be measured by both analytical methods and can show relatively similar groups. The PCA results show that there are three distinct groups (A, B, C) and two outliers for the ICP dataset but only one outlier for the pXRF. One ICP outlier becomes within group C in the pXRF dataset. When PCA scores are recalculated to include Th and Sr measured by pXRF, there was no significance difference.

In addition to examining the data in multivariate analysis, an attempt was made to show group discrimination using bivariate plots of the elements (Figure 6.10). The Th vs. Rb and Th vs. Nb plots measured by pXRF are best separating greenish from reddish ceramic sherds. In contrast, for ICP-MS data, good separation of green vs. red ceramic sherds is observed in bivariate plots based on Rb vs. Sr and Rb vs. Y. These elements work well for discriminating between groups. Overall, the dataset shows that, when carefully utilized, pXRF can be a useful and non-destructive tool for characterizing the chemical composition of ceramic artifacts. The

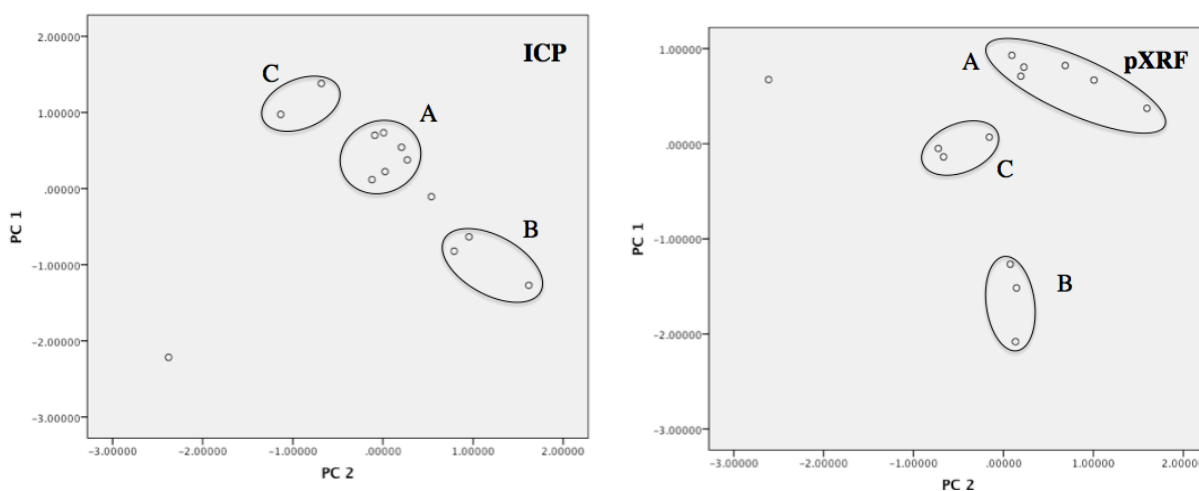
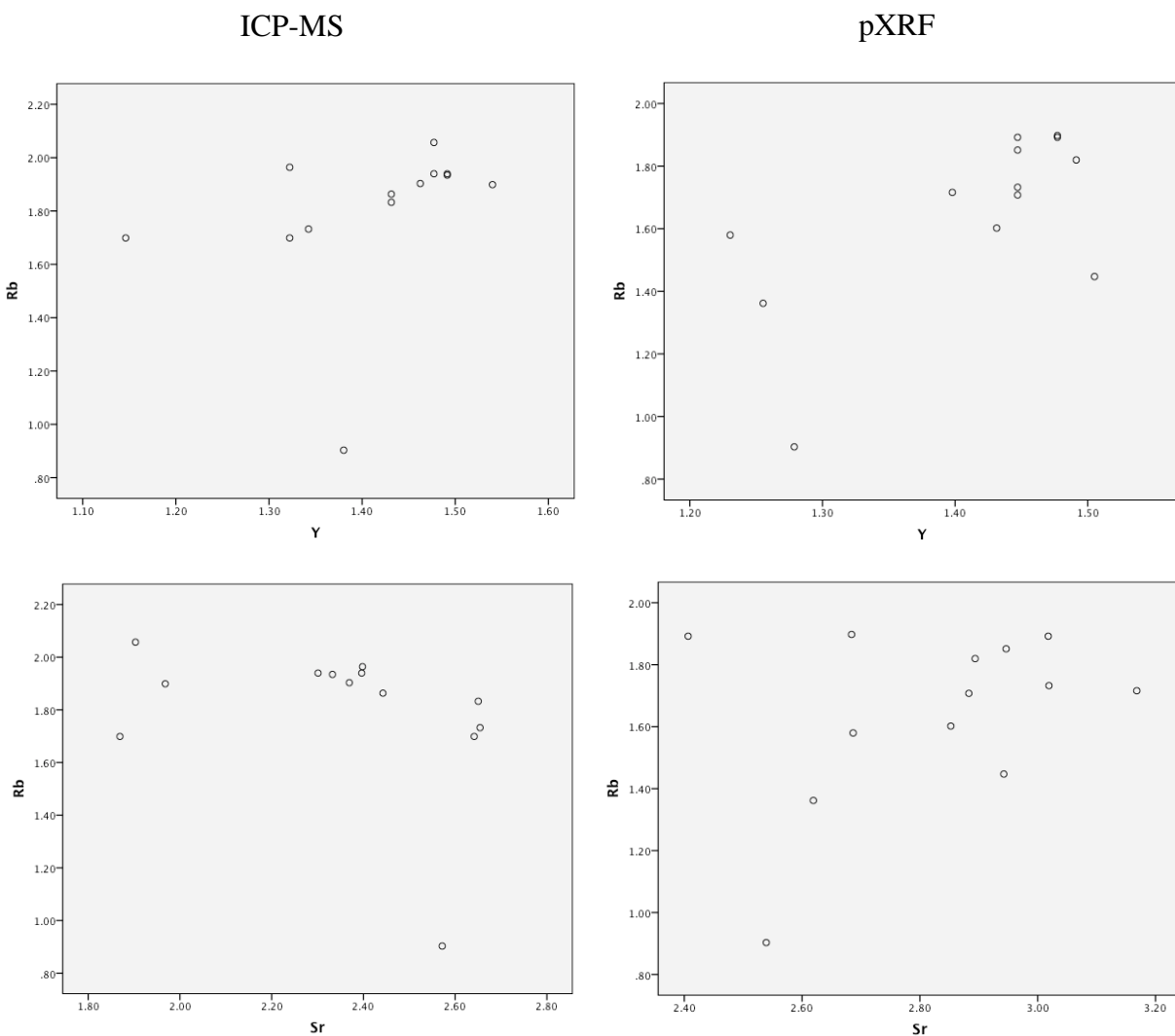


Figure 6.9 Biplot derived from PCA of covariance matrix of 13 pottery samples measured by ICP-MS and pXRF.

potential of maximizing pXRF for quantitative analysis would be possible if appropriate filter, calibration, and careful sample preparation and spot surface of beams exposure are utilized. The absence of direct 1:1 correlation between two dataset is also observed between pXRF and INAA when comparing the Mimbers pottery from the American Southwest. The results show that pXRF can present less separation than INAA but in general share the same INAA group structure (Speakman et al. 2011). Also, it shows that some pXRF ceramic data can appear as a marginal separating group. This is similar to the Dilmun ceramic data mentioned above.



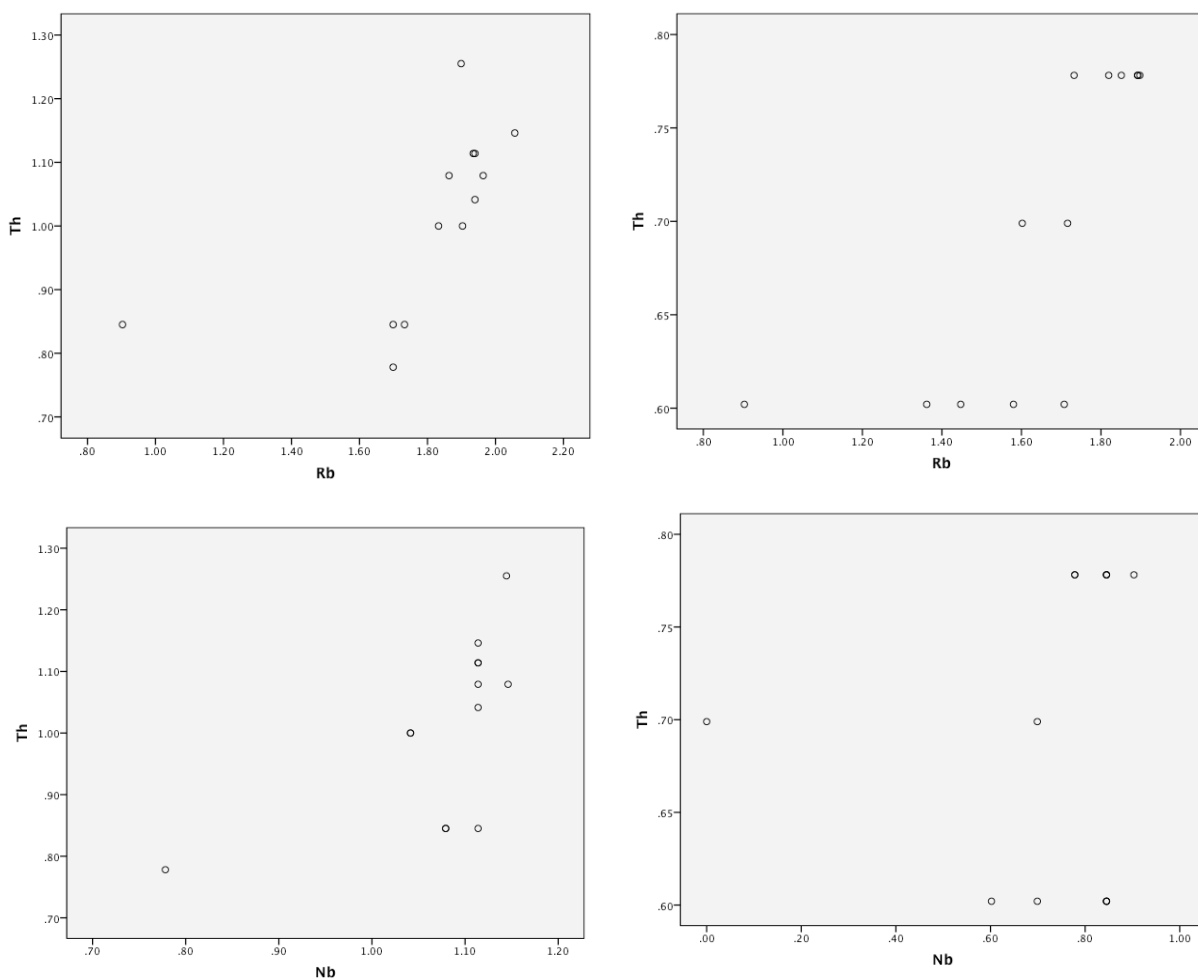


Figure 6.10 Elemental plots showing the best separation of samples analyzed by ICP-MS and pXRF using elements Rb, Sr, Th, and Nb.

### 6.3.3 Sample Preparation and Processing Data

The study samples were brushed to remove debris and dirt from excavation and museum storage, and then were washed and allowed to dry. After the cleaning of the potsherds, the elemental composition of the surface was analyzed non-destructively using a Bruker Tracer III-SD portable XRF. The instrument was set up with a filter (12 mm Al, 1 mm Ti, 6 mm Cu) placed in the X-ray path, for a 120-second live-time count, designed to enhance data measurements of mid-Z elements in the spectrum, with settings of 40 kV and 11  $\mu$ A selected to maximize trace element analysis (Robert Tykot, personal communication 2012). The new Si (PIN) detector in

the Bruker pXRF, that replaced a Si (Li) detector, supports the instrument's good performance and energy efficiency (Potts 2008; Shackley 2011). Only seven trace elements were measured and quantified as they show in the preliminary study their contribution for quantitative analysis including barium (Ba), niobium (Nb), rubidium (Rb), yttrium (Y), strontium (Sr), zirconium (Zr), and thorium (Th). They have been shown in many studies to be successful in determining sources and subsources of ceramic materials (Goodale et al. 2012; Hoeck et al. 2009; Speakman et al. 2011). Two major elements, manganese (Mn) and iron (Fe) were excluded due to fluctuations in the measurements, or values below the limits of detection determined in the preliminary results. After quantifying ceramic data using the calibration program, the values were saved in an Excel file for statistical assessment.

Each sample was set on the top of the exit window for 120 seconds to obtain elemental composition in parts per million (ppm) concentrations. The ceramic fragments tested are approximately 1-3 cm, and completely cover the beam size of this instrument, which is about 3x5 mm (Figure 6.11). The inner and outer surfaces of the samples were analyzed and the edges as well for thick samples to overcome the potentially poor representativeness of non-homogenized samples and to ensure that the results are consistent. The preliminary results showed that the multiple runs on different positions within the whole sample are consistent (see Figure 6.5 and Figure 6.6). Peak intensities for the Ka peaks of Rb, Sr, Y, Zr, Nb (and eliminated Fe and Mn) and La peaks of Th and Ba were calculated as ratios and converted to ppm. The data values used for each sample are reported as the average of the measurements at different positions (Appendix B).



Figure 6.11 pXRF at the Archaeological Science Laboratory, University of South Florida, Tampa. The lightweight of pXRF (2 kg/ 4.49 lbs.) allows users to conduct the analysis in the laboratory or in situ (photo by Hasan Ashkanani).

### 6.3.4 Statistical Analysis of Chemical Data

Numerous compositional ceramic studies (Aimers et al. 2012; Goren et al. 2010; Méry 2007; Mynors 1983; Speakman et al. 2011) have employed three main statistical methods: principal component analysis, cluster analysis, and discriminant function analysis. I also use these multivariate statistical approaches to find which elements can differentiate ceramic groups. Initially, I use simple scatterplots to show variations in chemical composition between samples even if they are not distinguishable visually. The aim of starting with simple scatterplots is to make some observations about possible clusters and possible problems interpreting the data, as an exploratory data analysis, and examine which elements can group the samples. This exploratory analysis will be followed by the three robust analyses to draw conclusions about compositional groups and outliers as well.

Multivariate statistics will be performed on all 304 samples to identify possible ceramic groups. Then, only ceramic sherds from Failaka Island will be subjected to multivariate analyses to explore any variation with Failaka Island sites. Also, each phase (e.g., Failaka Period 1 vs. Barbar IIb) will be subject to the same statistical procedure to focus on any variation within sites and phases and examine if the Dilmun ceramic of Failaka Island have any relation to the Bahrain collection.

Preliminary simple scatterplots were performed to discern any variation within each site and among Dilmun ceramics as well. This exploratory data analysis was useful in the determination about which elements, of the total seven obtained from pXRF, can differentiate and group ceramic groups.

#### **6.4 Petrographic Thin Sectioning**

The reliability of the instrument's performance cannot be understood without comparing its results to those results generated with other instruments such as INAA, ICP and petrographic microscopic thin section as well. For the purpose of this research, petrographic thin section analysis is the most important analytical method to evaluate the reliability of pXRF and also give invaluable information about the ancient technique of ceramic production. By employing pXRF and a petrographic microscopic thin section, it is possible to identify the raw materials and chemical and mineralogical composition (e.g. clay and tempering materials). The results obtained could contribute to the discussion about the peculiarities specific to each production center, such as Failaka Island and its regional trading partners.

#### **6.4.1 Sample Preparation for Petrographic Thin Sectioning Analyses**

Pertaining to the sampling issue, the statistical results indicate that there are only two main distinct chemical groups, Dilmun and Mesopotamia. Samples from each group were selected to identify their inclusions and confirm the pXRF results. The petrographic thin sectioning was applied only on early second millennium BC sherds (2000-1850 BC) that are parallel to Dilmun elite development.

Furthermore, sets of 25 samples were analyzed from Dilmun sites in Kuwait and Bahrain to determine the use of clays for particular production centers and to explore any scale of standardization of raw materials (Table 6.3). Because the big chemical group comprises all Kuwait and Bahrain Dilmun sherds and random sampling could be applied, as they are uniform, the judgmental sampling was rather applied to examine the degree of standardization of raw material selection and preparation of each ceramic type from each phase between Kuwait and Bahrain. For instance, within the Dilmun group, the selection of 12 samples was judgmentally based on comparing each ceramic type from each phase from Kuwait to similar ceramic types in Bahrain (Failaka Barbar type B vs. Bahrain Barbar type B). Also, the selection was based on comparing samples diachronically between Dilmun sites (early Failaka ceramic type A vs. late Bahrain ceramic type A) and within Dilmun sites (early Bahrain ceramic type B/C vs. late Bahrain ceramic type B/C). Finally, a selection was based on technique (Failaka ceramic type C wheel-made vs. Failaka ceramic type C hand-made) to discover if there is a relationship between the pottery techniques, the raw material selection, and preparation. The second group represents the mixed pattern of red and greenish Mesopotamian pottery. Thus, the judgmental sampling was also applied to make the comparison between wheel/hand-made red versus wheel/hand-made green sherds.



Table 6.4 A Summary of Sample Materials of Petrographic Thin Section Analysis.

Sample #	Kuwait site	Tradition – Type	Sample #	Bahrain site	Tradition - Type
<b>2000 - 1850 BC.</b> <b>Failaka Period 1 vs. Barbar II</b>					
13613	F6 Palace	Outlier	13661	Barbar II	Outlier
13617	F6 Palace	Dilmun - C	13662	Barbar II	Dilmun - C
13618	F6 Palace	Outlier	13664	Barbar II	Dilmun - B
13620	F6 Palace	Outlier			
13622	F6 Palace	Dilmun - A			
15128	Trench E	Dilmun			
<b>1850 – 1800 BC.</b> <b>Period 2A vs. Barbar III APR</b>					
13631	F3	Dilmun – Wheel C	13676	Barbar III	Dilmun - B
13634	F3	Dilmun – Hand B	13679	Barbar III	Dilmun - A
13701	Al-Khidr	Dilmun	13681	Qala'at	Dilmun - C
14231	Al-Khidr	Grayish			
14235	Al-Khidr	Dilmun			
14259	Al-Khidr	Grayish			
14270	Al-Khidr	Outlier			
14288	Al-Khidr	Dilmun			
<b>2100 BC.</b> <b>Mesopotamian House (reference group)</b>					
15154	F6	Red-wheel			
15156	F6	Green-wheel			
15158	F6	Red import?			
15166	F6	Hand-green			
15167	F6	Hand-red			

A set of 25 sherd samples that were representative of the Early Dilmun on Failaka Island and Bahrain had 25 X 46 mm thin sections prepared at the University of South Florida's Center for Geochemical Research. Before mounting the samples on glass, the samples were cut at 1-2 cm and sonicated in ultra-pure DI water and rinsed thoroughly in order to remove soil and dust particles. After completely drying in a low-temperature drying oven, the samples were glued on the glass and a sample number assigned for the glass section. After drying, the sample was

placed in a cutting and trimming machine to make the sample very thin. Weights were used on the ceramic mounting arm to apply cutting consistently over the sample surface. After cutting, the sample was also polished using a rock slab polishing station to make the surface very fine, presumably 30 microns. All thin sections were brought to the Department of Geology, University of South Florida, and were examined under a Nikon Eclipse LV100 POL polarizing microscope under the assistance of Ciprian Stremtan. The examination of samples under microscopy was done at 10X, 20X, and 100X magnification, depending upon the visibility of inclusions and homogeneity of the sample paste.

#### **6.4.2 Processing Data for Petrographic Thin Sectioning Analyses**

Two sets of 25 thin section slides were prepared for examination. The first set was examined using microscopy with the assistance of Ciprian Stremtan. All observations were recorded including visible inclusions, main minerals, secondary minerals, grain shape, mineral features and alteration, and textural descriptions as well. A second set of 25 slides that represent early Bronze Age ceramics was sent to Dr. Mary Ownby (Desert Archaeology, Inc.). Ownby provided a description and grouping of the samples. While the first data set was insufficient to determine patterns of Bronze Age pottery production, data obtained from the second of 25 ceramic samples, in addition to slide description and groupings, are presented in Appendix C.

## **CHAPTER SEVEN: RESULTS – ANALYTICAL AND STATISTICAL RESULTS OF CHEMICAL DATA**

### **7.1 Introduction**

The results of this inquiry include the data sets generated from the pXRF device, petrographic thin sectioning analyses, and the statistical analysis of comparing the data sets of the latter. Furthermore, the assessment of the pXRF data by multivariate statistical analysis has provided valuable details about the homogeneity of Dilmun ceramics and the circulation of non-local pottery within the Dilmun realm. The results suggest the existence of a number of ceramic groups and illustrate the outliers. Also, the results support the reliability of the use of the pXRF technique when juxtaposed to the results from the petrographic thin section analyses.

### **7.2 Statistical Analysis of Chemical Data**

A simple scatterplot of trace elements Rb, Nb and Sr shows differentiation between and within sites (Figure 7.1). It shows that there are three distinct groups. The Indus valley collection is well separated from the Dilmun and Mesopotamian collections. One group includes all Dilmun ceramic sherds from Kuwait and Bahrain. The second group includes the Mesopotamian and Iranian collection in addition to some outliers from Barbar temples in Bahrain and the F3 site on Failaka Island. Some scattered samples are shown out of these distinct groups, suggesting more possible subgroups within Mesopotamian and Iranian collections.

A simple scatterplot of trace elements Rb and Sr suggest a different composition within Dilmun sites on Failaka Island and Bahrain (Figure 7.2). It shows that sherds from the Mesopotamian House on Failaka Island and Iranian sherds are well separated. This group includes some outliers from Dilmun sites, particularly from the F3 site in Kuwait. The large group consists of Dilmun sherds from Failaka Island sites and Bahrain. Interestingly, it is still showing some samples from the F3 site's later period as scattered and unmatched to any group.

A simple scatterplot of trace elements Ba, Rb, and Y was performed to include 90 samples from the Al-Khidr site on Failaka Island (Figure 7.3). The results show that there is also a differentiation within the Al-Khidr site. Most of the Al-Khidr sherds are clustered with the Dilmun group while a few outliers overlap with the Mesopotamian House group. The presence of Rb, Sr, Nb, Ba and Y confirms the variation within and between the Dilmun archaeological sites. Also, some ceramic sherds from Dilmun sites in both Kuwait and Bahrain overlap with non-local/Dilmun groups. These results have added an interesting avenue to discuss the interaction between different polities from this era.

### **7.2.1 Principal Component Analysis for all Research Collections**

A variety of statistical applications were employed to evaluate the data collected using SPSS statistical software. Principal component analysis (PCA) was the exploratory method used to examine the correlation between chemical elements, to suggest which variables or groups of elements are meaningful, and to account for the maximum variance in the data set.

Transformation of the dataset into logarithms was performed to standardize the data. The SPSS component matrix was useful because it contains the loading of each variable onto each factor. The results showed that only two component factors could explain to the variance (Table 7.1),

71.4%. It also showed how, for instance, Sr contributed highly (.981) in the first component while lower in the second component (.345).

A scatterplot was performed using PCA scores 1 and 2 that included Nb, Th, Sr, Y, Zr, Rb, and Ba, which previously showed their high contribution in the component matrix. The results show two distinct groups of ceramics (Figure 7.4), while the Palace, Trench E and the Barbar Temple were clustered together (group A). It also showed a distinct group of samples including the Mesopotamian House with a few outliers from the Barbar Temple and Trench E (group B). There were two outliers from the Palace; one was a pronounced outlier. The PCA results show the separation of sherd samples between and within the archaeological sites.

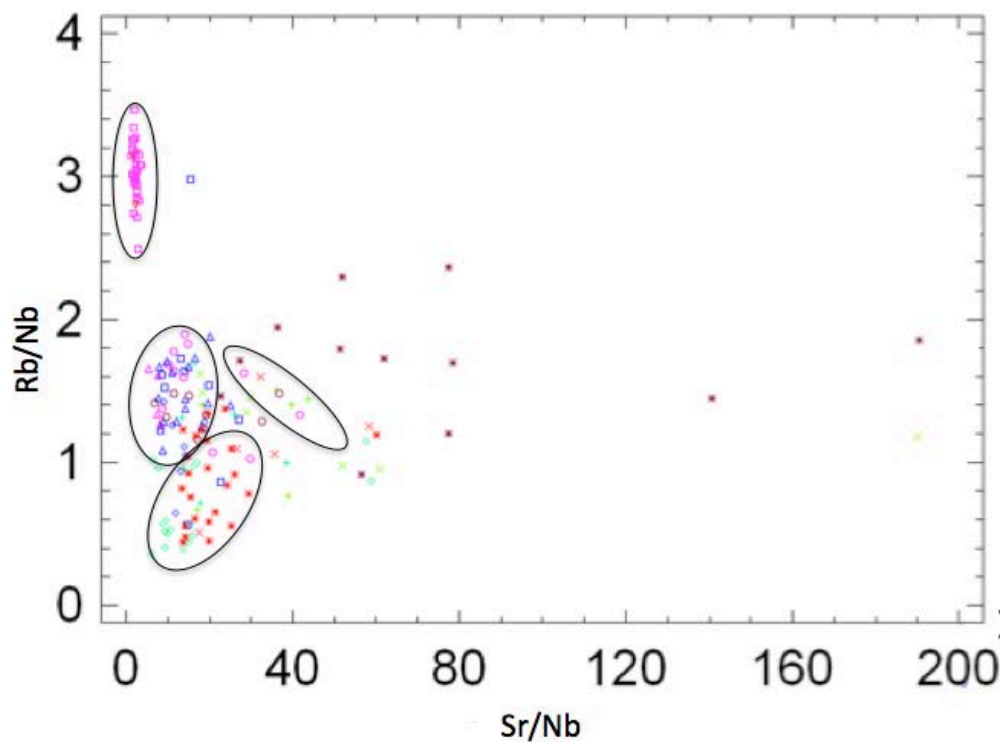


Figure 7.1 A biplot of Rb/Nb vs. Sr/Nb discriminating between and within sites and separating the Indus Valley collection (pink square) from Dilmun (pink circle and blue triangle) and Mesopotamian and Iranian sherds (green and red).

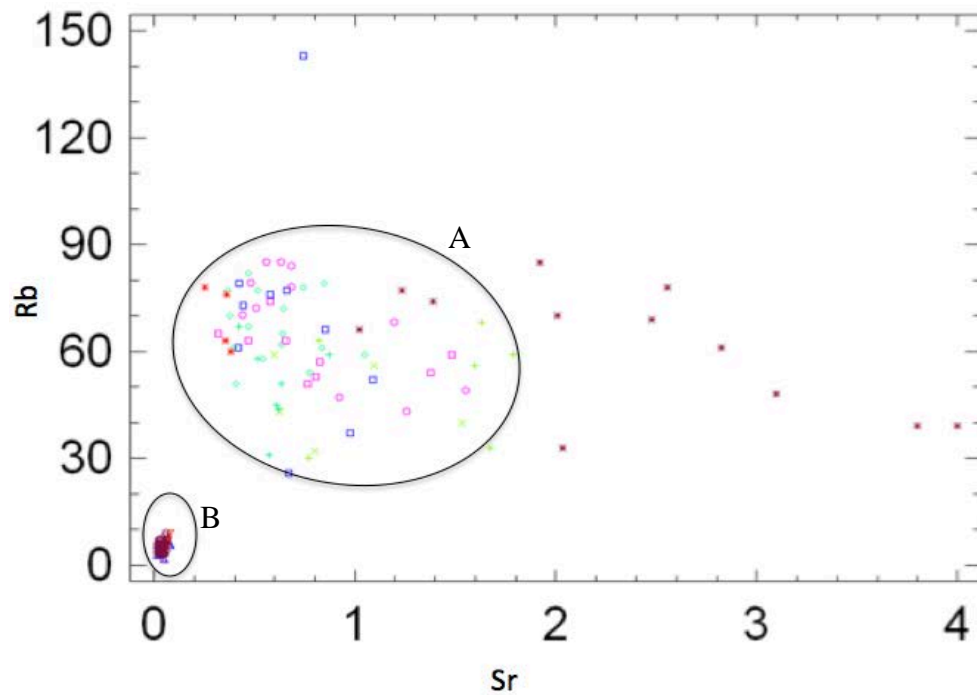


Figure 7.2 A biplot of Rb and Sr showing the best separation of groups/samples between Dilmun sherds (A) and Mesopotamian-Iranian (B). Some samples from Dilmun sites overlap with the Mesopotamian group.

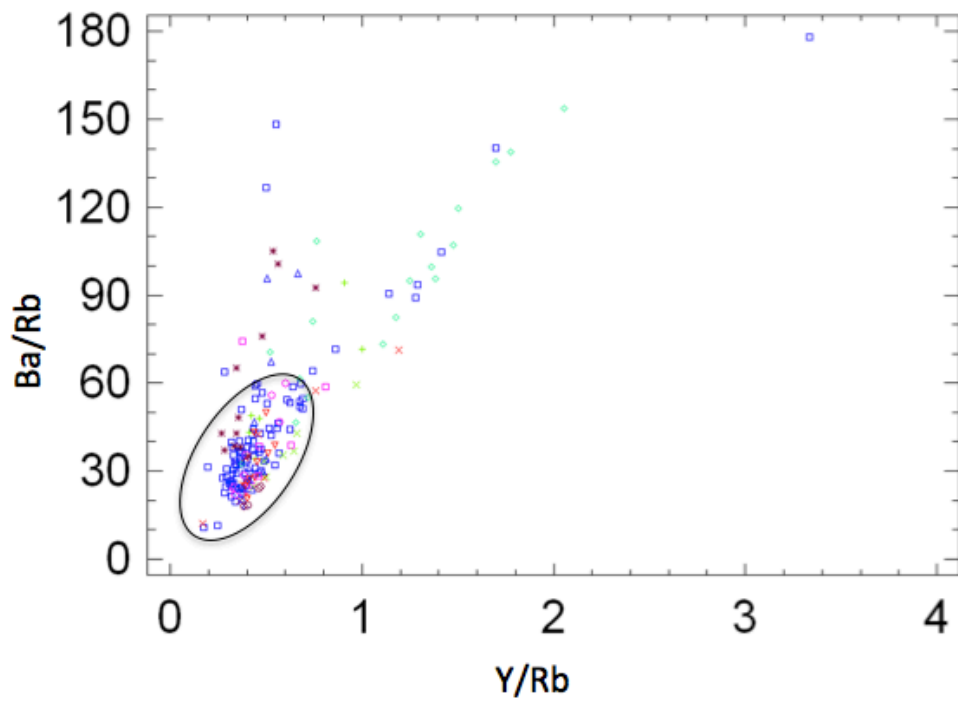


Figure 7.3 A biplot of Y/Rb vs. Ba/Rb showing the Al-Khidr sherds (blue circle) within the Dilmun group and some outliers overlapping with the Mesopotamian House collection (green diamond).

Table 7.1 Component matrix of each variable loading.

	Component	
	1	2
Sr_Log	.891	.345
Th_Log	.891	.168
Nb_Log	.814	.081
Rb_Log	.754	.354
Ba_Log	.650	.554
Y_Log	.563	.076
Zr_Log	.449	.802

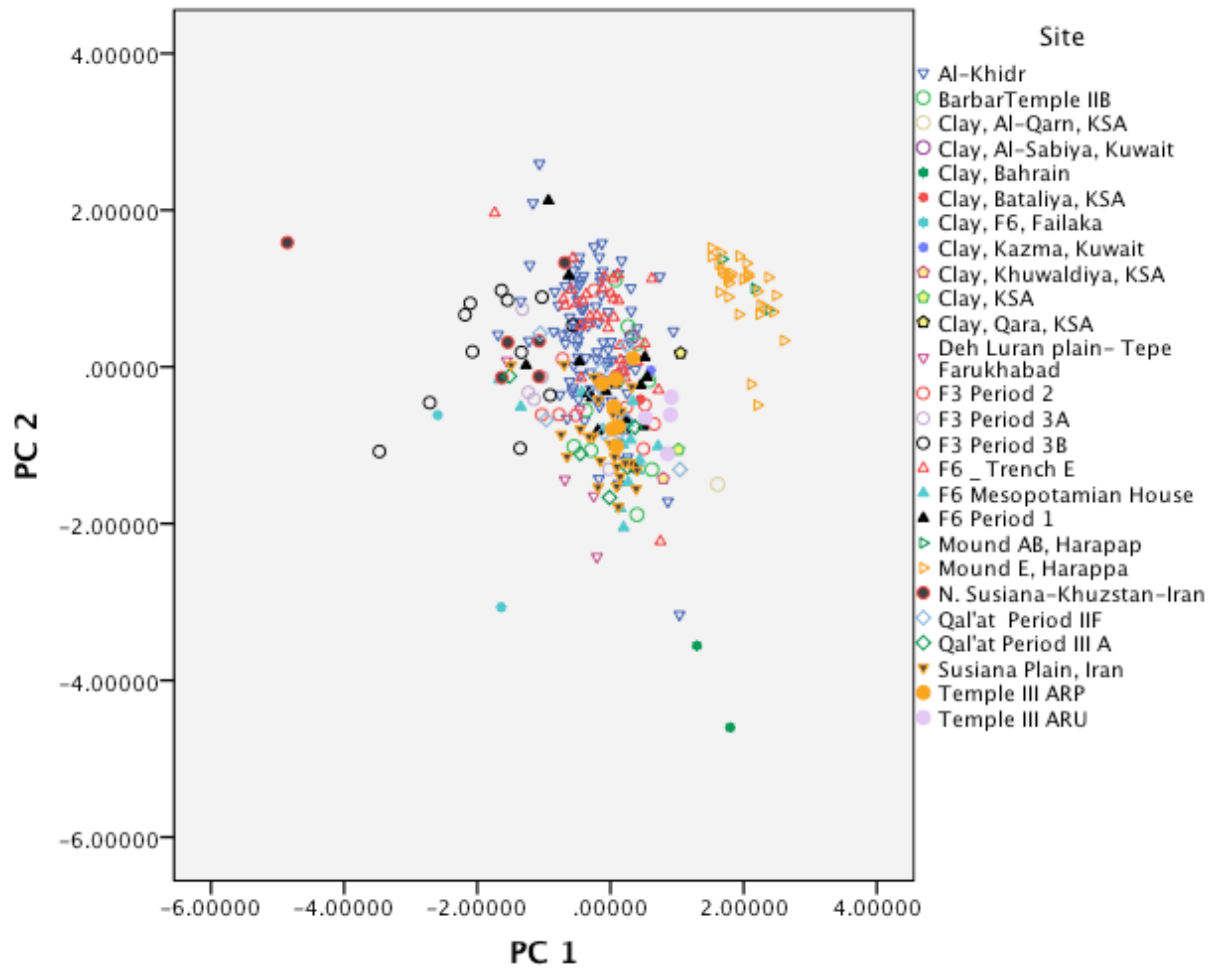


Figure 7.4 Biplot derived from PCA of 304 sherd and clay samples measured by pXRF, showing variation within Failaka Island and Bahrain sites. At least two distinct groups of ceramics (Harappa vs. Dilmun) are noticed and potential outliers from Al-Khidr, F3, and F6 in Kuwait and the Deh Luran region.

### **7.2.2 Cluster Analysis of all Research Collection**

The principal component analysis was followed by a cluster analysis using PCA scores, which included all 7 elements (Nb, Th, Sr, Y, Zr, Rb, and Ba), for identifying natural groupings and evaluating PCA results. K-means cluster analysis was used for the clustering method because it groups all samples and then finds clusters. K-means cluster analysis is useful to test our research questions about the presence of more than two groups of ceramic sherds, as it can explore the number of groups. The ANOVA output is the most important aspect in cluster analysis as it distinguishes which factor is great and statistically significant (.000). The cluster analysis also groups the data based on presuming a number of clusters to test the PCA scores. Five clusters have been proposed for this analysis. The number of clusters was selected based on the simple scatterplot in the exploratory analysis. The number of clusters could also be selected based on the assumption of different numbers of production centers relative to each region and/or site collection. The ANOVA results showed that all PCA factor scores are statistically significant, proposing five clusters. The cluster analysis plot (Figure 7.5) showed that there are at least three distinct groups separating the 304 samples.

### **7.2.3 Discriminant Function Analysis**

Discriminant function analysis (DFA) was employed as a different quantitative technique to discriminate between groups and classify the samples into different production centers. The original log data were used for all seven elements (Nb, Th, Sr, Y, Zr, Rb, and Ba) as variables and site names as a grouping variable. Within a grouping variable, there is a step to define the range of groups and, based on that the DFA will produce PCA scores. I assumed a minimum of



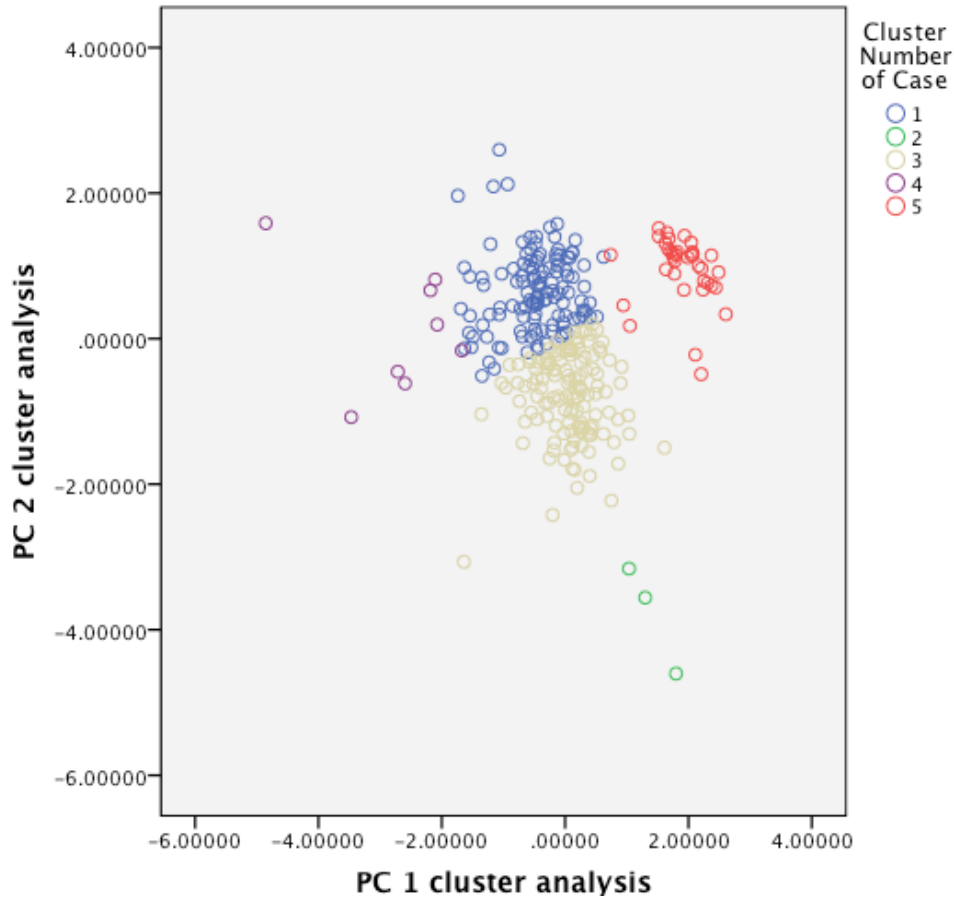


Figure 7.5 Plot using PCA scores and presuming 5 clusters showing at least three distinct groups in the sample collections.

two groups to a maximum of six groups, based on the assumption of production centers that the samples might have been made at are limited to Dilmun of Failaka and Bahrain, Mesopotamia, the Indus Valley, and the Iranian plateau. The canonical discriminant function plot showed that the ceramic sherds and clay samples are separated into a minimum of two main groups (Figure 7.6).

Similar to the PCA component matrix, DFA also produces a matrix of function, based on the presuming groups, showing the contribution of each variable in the DF function. The results showed that there are only four significant discriminant functions. For instance, the result showed that Ba is highly contributed in DF 1 and 3, while Y is highly contributed in DF 2 and 4

(Table 7.2). The Wilk output showed that including the first discriminant function with any other functions are statistically significant (.000), while excluding the first function, the grouping will be less significant. Based on the Wilk output, a scatterplot was performed using discriminant functions DF1 and DF4 (Figure 7.7). The plot showed that there are at least four clusters representing a collection from the Indus Valley, Dilmun, north Susiana, and a mixed group of outliers from Failaka sites. Also, some outliers are from Al-Khidr, F3, Qala'at, north Susiana, and clay samples from Kuwait and Bahrain. Based on statistics, 78.3% of the original grouped cases are correctly classified. The percentage of correct classification of defining a range of two to six groups is higher than selecting presumed 3 or 4 groups, which show less than 73% (~72.3 – 65.5%) in the pilot study.

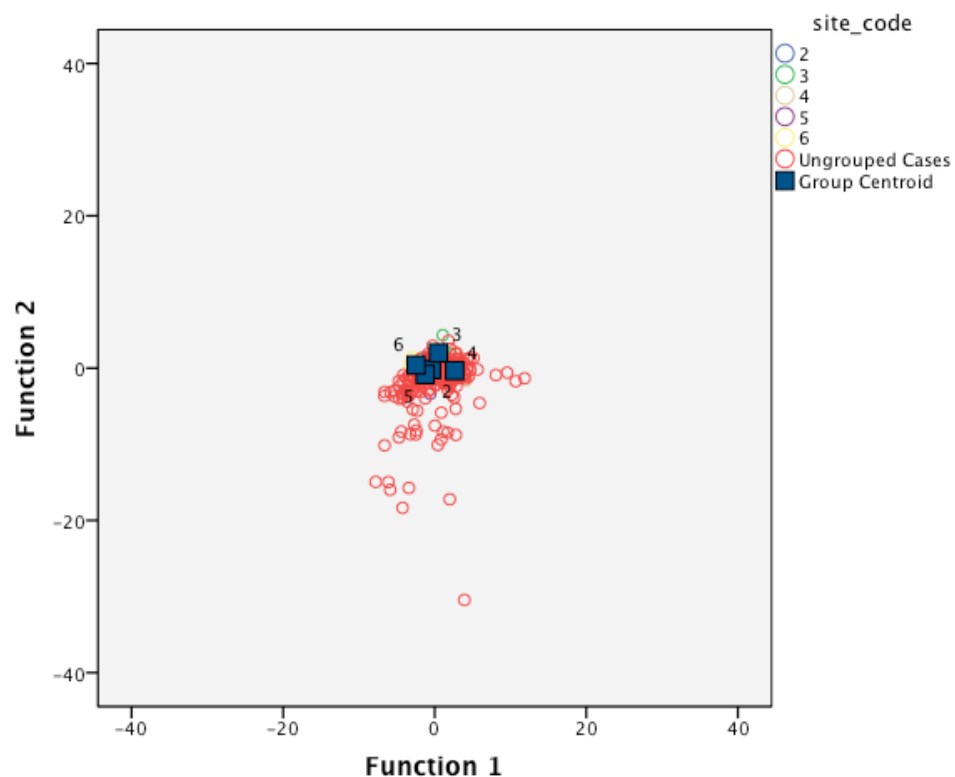


Figure 7.6 Canonical discriminant functions 1 and 2 showing at least two main distinct groups and a large number of ungrouped samples.

Table 7.2 Loading of each variable into each discriminant function.

	Function			
	1	2	3	4
Ba_Log	1.095	.131	.968	.299
Th_Log	.418	1.045	.132	.022
Rb_Log	.298	.466	.804	.615
Sr_Log	.149	1.171	.346	.529
Y_Log	.081	1.114	.289	1.018
Zr_Log	.236	.185	1.122	.488
Nb_Log	.015	.546	.803	1.408

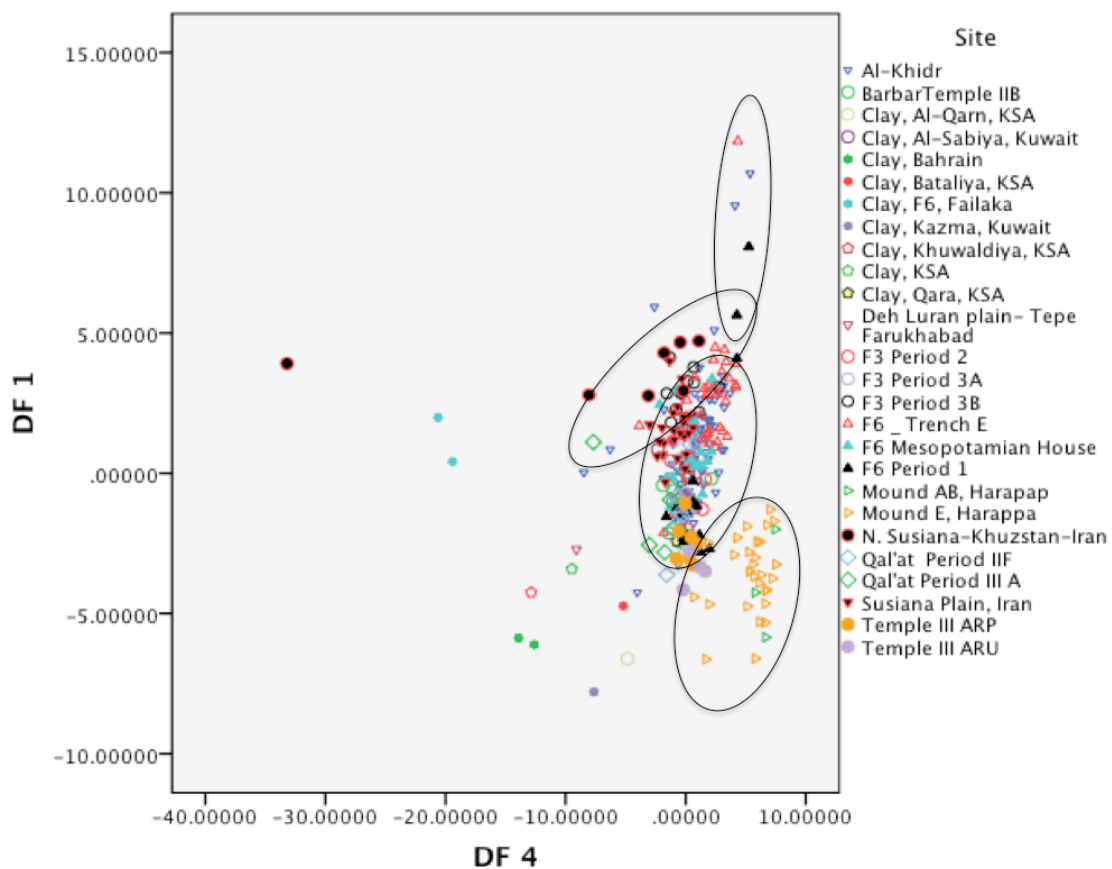


Figure 7.7 Biplot of discriminant scores on discriminant function 1 and 4 showing a mixed pattern of specimens from Kuwait and Bahrain sites, along with a well-separated group of the Indus Valley. 78.3% correctly classified. Ellipses are made artificially.

Based on the quantitative analyses, there are at least three groups. The first group is comprised of Dilmun sherds from Kuwait and Bahrain. This cluster includes all ceramics from

all phases with overlapped sherds from Susiana Plain in Iran and the Mesopotamian House on Failaka Island. The second group is comprised of sherds from Harappa Mound AB and Mound E. None of the Harappan sherds were outliers or overlapped with the samples from Failaka Island or Bahrain, except for a few samples from the NE Temple (III) ARU in Bahrain which are close with those Indus Valley collections. The third group presumably consisted of North Susiana in Iran and a few outliers from Qala'at Period IIIA of Bahrain, Al-Khidr on Failaka Island, Trench E at F6 and probably the Palace on Failaka Island. The last group of sherds was the outliers. Most of those outliers appear in the PCA bivariate plot (see Figure 7.4), particularly samples from North Susiana, Al-Khidr, Trench E at F6, the Palace, and clay samples from Bahrain and F6 on Failaka Island. The PCA biplot showed some outliers from the F3 site on Failaka Island but not in the discriminant analysis. The clay samples have not proven useful as a reference group of different geological areas. All clay samples from Bahrain, Kuwait and KSA were outliers and only two clay samples from north Kuwait and Qara in Kuwait overlapped with the Dilmun group. The others were too far from any sherd collections. They clustered alone with an exception, of one clay sample that is similar to a Deh Luran plain sherd. Thus, clay samples have appeared to be unreliable as a standard to source Dilmun artifact collections as was presumed (Jonathan Kenoyer, personal communication, 2011). Based on multivariate analyses, the clay itself could not be compared with the ceramic sherds as they were made of clay and additive temper to keep them from cracking or shrinking during the firing process

By combining all the research samples, it was not possible to determine properly any outliers from any individual sites or to explore any overlapping within and between sample groups. Even though the quantitative analyses showed some distinct clusters and major outliers, it was better to run multivariate analyses. In general, excluding the Harappan sherds allowed me

to maximize the variation and to find any differences within the Dilmun sites. The Mesopotamian House samples are included as a reference group of Mesopotamian clay and to find properly any overlap.

#### **7.2.4 Principal Component Analysis for all Failaka Island Ceramic Sherds**

A total of 189 ceramic potsherds from all Failaka Island sites were analyzed (Table 7.3). The samples were selected from all Bronze Age sites on Failaka Island, representing all phases beginning from the early to mid-second millennium BC. Only the Mesopotamian House sherd collection came from the late third millennium BC, particularly from the Ur III house structure within tell F6. As with the above multivariate analyses using SPSS, transformation of the dataset into logarithms has been performed to standardize the data. The results showed that three component factors could contribute to the variance (Table 6.4), which was 80% of the variance. It also showed, for instance, how Sr, Nb, and Y contribute highly in the first component while Rb, Zr, and Th do so in the second component.

A scatterplot was performed using PCA scores 1 and 2 that include Nb, Th, Sr, Y, Zr, Rb, and Ba, which previously showed their high contribution in the component matrix. The results showed two distinct groups of ceramics (Figure 7.8), while the Palace, Trench E and Barbar Temple are clustered together (group A). It also showed a distinct group of samples including the Mesopotamian House with a few outliers from the Barbar Temple and Trench E (group B). There were two outliers from the Palace and one was quite distinct. Also, outliers from F3 Period 3A and Trench E of F6 are overlapped with the Mesopotamian House group. A distinct group of F3 Period 3B is well separated as a third group. The PCA results showed the separation of sherd samples between and within the archaeological sites.

### 7.2.5 Cluster Analysis for all Failaka Island Ceramic Sherds

The PCA is followed by a cluster analysis using PCA scores, which include all 7 elements (Nb, Th, Sr, Y, Zr, Rb, and Ba), for identifying natural groupings and evaluating PCA results. K-means cluster analysis was utilized for the clustering method based on presuming four clusters to possibly group all samples. The ANOVA output, which is the most important aspect in cluster analysis in order to see which factor is great and statistically significant, shows that the first three PCA factor scores are statistically significant ( $p < 0.05$ ). A scatterplot was performed using PCA 1 and 2 and set markers by the scores of the presumed four groups produced by the cluster analysis. The results show that there are two distinct groups with a few outliers (Figure 7.9).

Table 7.3 Summary of sample materials of all Failaka Island sites.

Site	Structure	Sample Size	Phase
Tell F6	The Palace	16	Period 1
Tell F6	Trench E	35	Period 1
Tell F6	Mesopotamian House	18	Pre-Period 1
Al-Khidr		91	Period I-2
F3		11	Period 2
F3		6	Period 3A
F3		12	Period 3B
		Total 189	

Table 7.4 Component matrix of each variable loading.

	Component		
	1	2	3
Sr_Log	.872	.049	.332
Nb_Log	.859	.280	.108
Y_Log	.837	.242	.180
Th_Log	.616	.573	.103
Rb_Log	.022	.901	.107
Zr_Log	.013	.726	.377
Ba_Log	.078	.101	.943

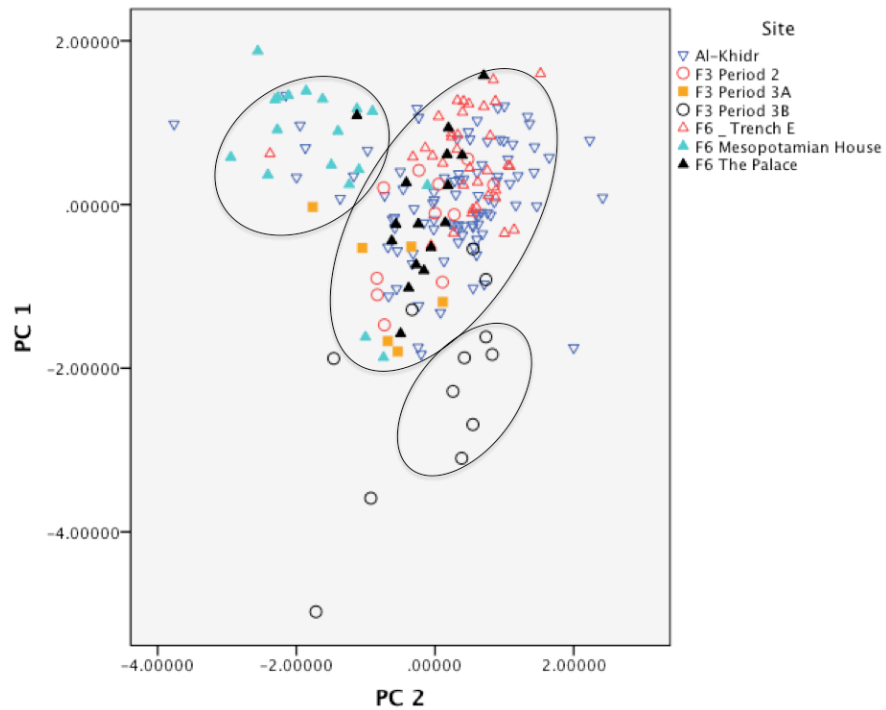


Figure 7.8 Biplot derived from PCA of 189 samples measured by pXRF, showing variation between Failaka Island sites. Ellipses are made artificially.

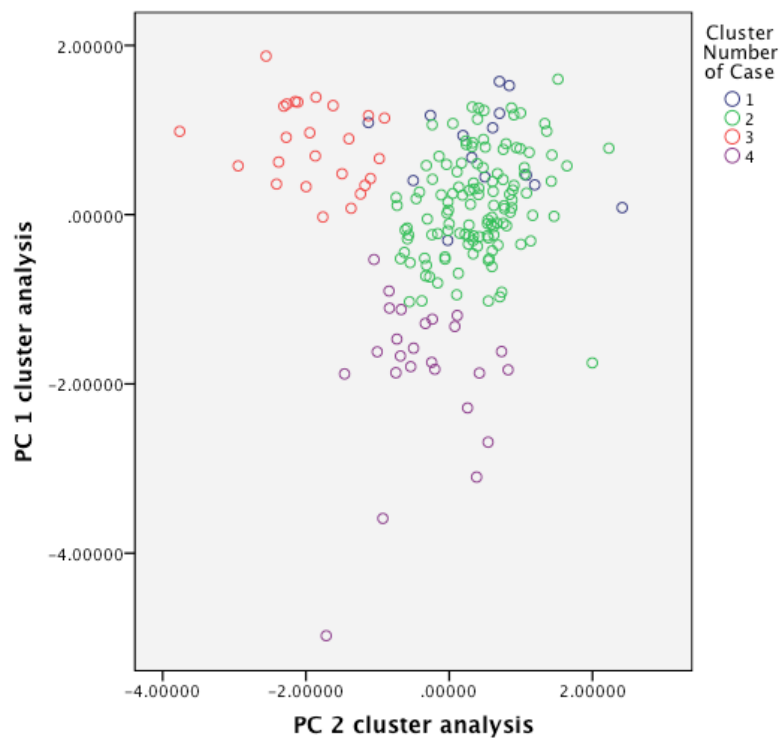


Figure 7.9 Plot using PCA scores and presuming 4 clusters showing at least two distinct groups with a few outliers.

### **7.2.6 Discriminant Function Analysis for all Failaka Island Ceramic Sherds**

DFA was employed as a different statistical technique to discriminate between groups and classify our samples into different production centers. The results showed that DFA was able to produce three discriminant functions that significantly grouped the dataset (Table 7.5). Again, in order to perform DFA, a range of groups should be defined, based on exploratory analysis or the research assumption. It is assumed that there are minimums of two to a maximum six groups as performed in the above discriminant analysis of all research sample collections. Original log data were used for all seven elements (Nb, Th, Sr, Y, Zr, Rb, and Ba) as variables and site names as a grouping variable. The canonical discriminant function plot showed that the ceramic sherds were separated into two main groups, with a potential small group (Figure 7.10).

The canonical plot shows clearly the offset of centroid 3 and 4 from the rest of the group.

The canonical plot clearly illustrated the offset of centroid 3 and 4 from the rest of the group. The Wilk's output showed that the three discriminant function scores were statistically significant ( $p < 0.05$ ) if DF1 is included with any of the other two functions. Thus, a scatterplot was performed using discriminant scores on the discriminant axes (DF1, DF2) to determine if those functions are able to group samples (Figure 7.11). Ceramic potsherds were distinctly grouped into three main groups, more so than with PCA and cluster analysis. Those groups that formed the big cluster (group A) come from Al-Khidr, F3 Period 3A and 3B, the Palace and Trench E, with at least one overlapping sample from the Mesopotamian House. Group B consists of samples from the Mesopotamian House on Failaka Island and the overlapping eight samples from Al-Khidr, three samples from F3 Period 3A, and one from Trench E, F6 and F3 Period 2 as well. Group C has eight outliers all from F3 Period 3B. This group obviously appeared in the PCA plot as a potential third group. Finally a possible group D is clustered between the main



three distinct groups that consist of mixed specimens from Al-Khidr, the Mesopotamian House and F3. Based on statistics, 71% of the original grouped cases are correctly classified.

In addition, to the four groups of potsherds, there were nine outliers that appeared in the left part of the scatterplot. They are from Al-Khidr and Trench E in Tell F6. Unlike the multivariate analyses of all research samples, analyzing only Failaka Island potsherds showed more variations between sites. The Al-Khidr potsherd collection seemed to have more outliers than the previous multivariate analyses. The outliers overlapped with the Mesopotamian House or clustered alone. The individual outliers of Al-Khidr were so scattered and unlike, there is no potential grouping pattern. Moreover, the Mesopotamian House was so distinct as a separate group more than after including non-Failaka sites. It showed that there were overlapping samples from F3 and Trench E with the Mesopotamian House group.

### **7.2.7 Principal Component Analysis for Ceramic Sherds of all Kuwait and Bahrain Sites**

A total of 224 ceramic potsherds from all Failaka Island sites and Bahrain were analyzed (Table 7.6). The samples were selected from all Bronze Age sites on Failaka Island and Bahrain, representing all phases beginning from the early to mid-second millennium BC. The goal was to see if there were any discernable chemical groups for Dilmun pottery, if the Failaka ceramics were grouped with Bahraini collections. As with the above multivariate analyses using SPSS, transformation of the dataset into logarithms was performed to standardize the data. The results showed that three component factors could contribute to the variance (Table 7.7), which could explain 80% of the variance. It also showed, for instance, how Nb, Sr, and Th highly contribute in the first component, while Ba and Zr in the second component.

Table 7.5 Loading of each variable into each discriminant function.

	Function		
	1	2	3
Ba_Log	.685	1.847	3.672
Th_Log	6.012	6.000	5.160
Rb_Log	.956	1.581	1.374
Sr_Log	5.679	8.984	4.220
Y_Log	5.973	32.642	7.001
Zr_Log	1.078	5.352	9.559
Nb_Log	4.053	18.742	6.226

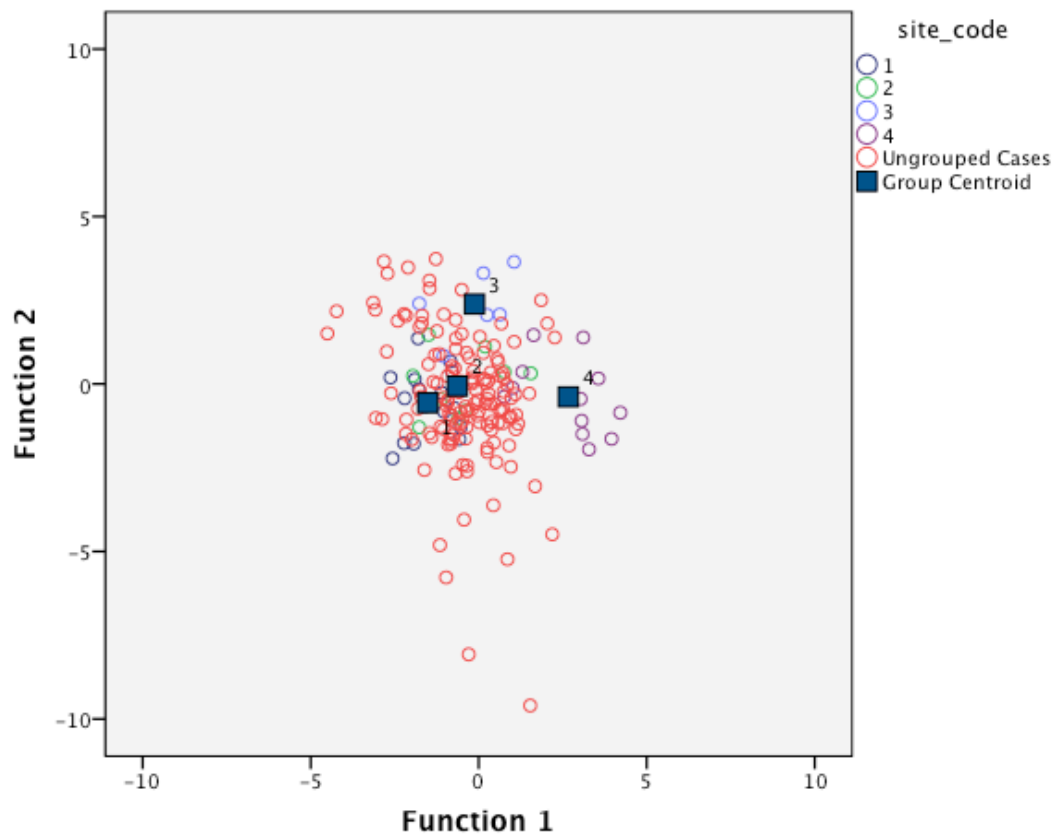


Figure 7.10 Biplot based on discriminant functions showing at least two (centroid 1, 2 vs. 4). Ellipses are made artificially.

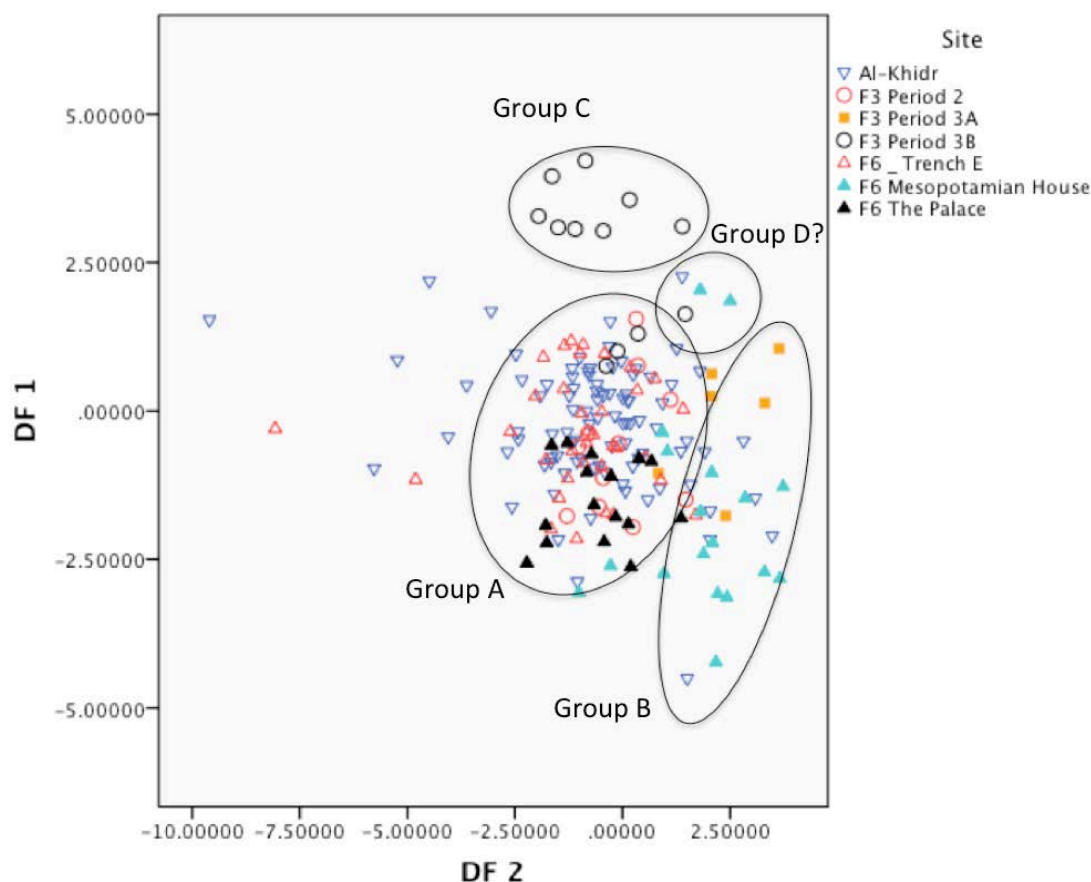


Figure 7.11 Biplot of DF 1 and 2 showing a mixed pattern of Dilmun sherds (group A), along with other two groups (B and C). 71% correctly classified. Ellipses are made artificially.

A scatterplot was performed using PCA scores 1 and 2 that include Nb, Th, Sr, Y, Zr, Rb, and Ba, which previously showed their high contribution in the component matrix. The results showed two distinct groups of ceramics (Figure 7.12), separating Dilmun collections (Group A) from the Mesopotamian House (Group B) in which some outliers from other sites overlapped. It also showed that there were two possible groups: the F3 sherds and one sample from Qala'at, and a small group of two sherds from Al-Khidr and one from Barbar Temple. The large group consisted of all Dilmun collections from Kuwait and Bahrain and one overlapping sherd from the Mesopotamian House. The second distinct group is well separated and consisted of the Mesopotamian House collections and overlapping sherds from Al-Khidr, the Palace, Trench E,

F3, Barbar Temple, and Qala'at in Bahrain. A small distinct group of F3 Period 3B was well separated as a third group. Some sherds were outliers that did not overlap with any PCA groups. Using principal components 1 and 2 showed the well separation of sherd samples between and within the archaeological sites from Failaka Island and Bahrain.

Table 7.6 Summary of all materials from Kuwait and Bahrain.

Site	Structure	Sample Size	Phase
Tell F6	The Palace	16	Period 1
Tell F6	Trench E	35	Period 1
Tell F6	Mesopotamian House	18	Pre-Period 1
Al-Khidr		91	Period I-2
F3		11	Period 2
F3		6	Period 3A
F3		12	Period 3B
Barbar	Barbar Temple II	10	Period IIb
Qala'at		9	Period IIF
Qala'at		5	Period IIIA
Barbar	Barbar Temple III	7	ARP
Barbar	Barbar Temple III	4	ARU
		Total 224	

Table 7.7 Component matrix of each variable loading.

	Component		
	1	2	3
Nb_Log	.896	.141	.039
Sr_Log	.804	.473	.107
Th_Log	.766	.353	.004
Y_Log	.638	.355	.513
Zr_Log	.330	.746	.004
Rb_Log	.440	.607	.514
Ba_Log	-.080	.640	.694

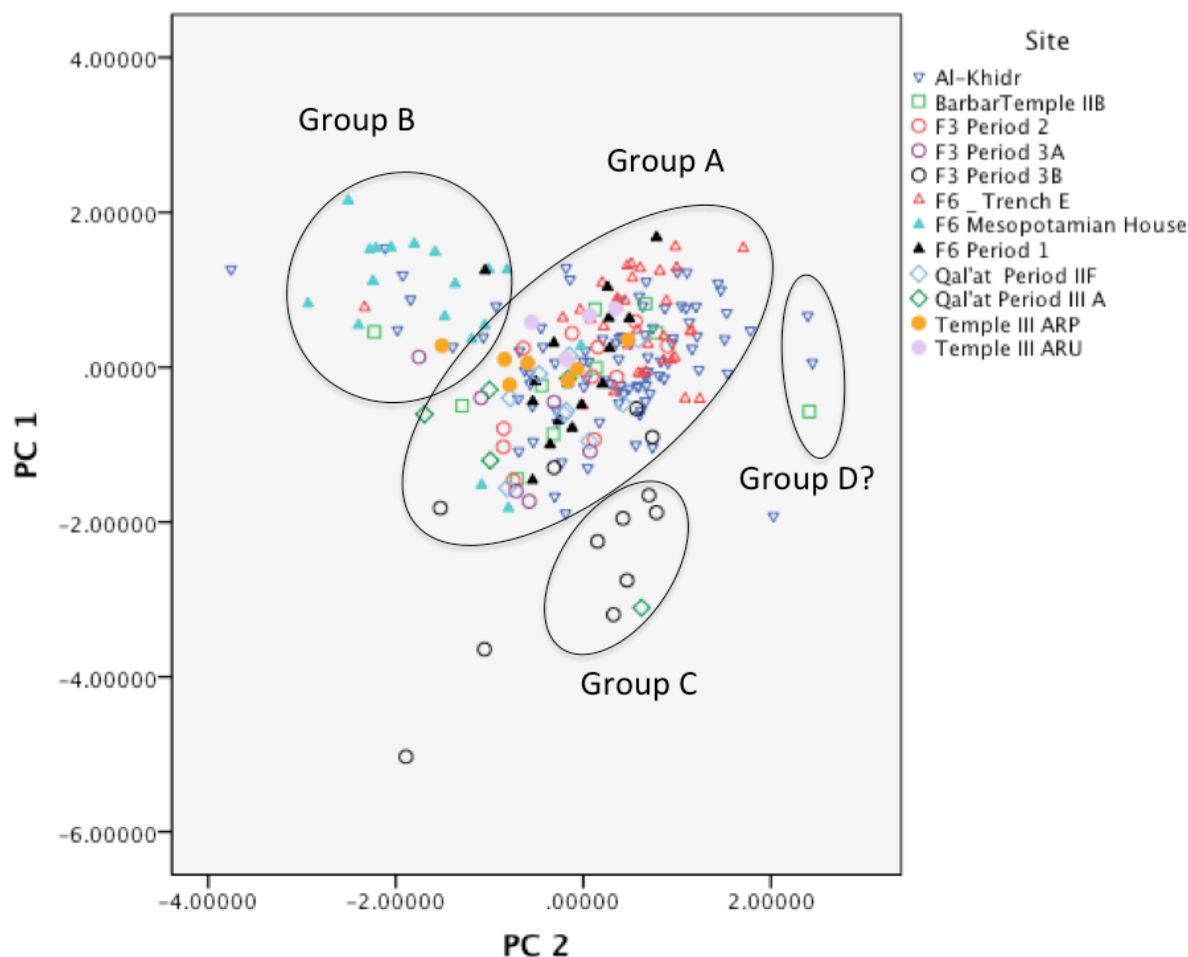


Figure 7.12 Biplot derived from PCA of 224 samples. Note the match among Dilmun pottery from Kuwait and Bahrain and a few outliers from Al-Khidr and F3. Ellipses are made artificially.

### 7.2.8 Cluster Analysis for Ceramic Sherds of all Kuwait and Bahrain sites

The PCA is followed by a cluster analysis using PCA scores, which included all 7 elements (Nb, Th, Sr, Y, Zr, Rb, and Ba). The ANOVA output showed that the first three PCA factor scores were statistically significant ( $p < 0.05$ ). The scores of the presumed four groups, produced by the cluster analysis, performed a scatterplot using PCA 1 and 2 and set markers. The results showed that there were two distinct groups with a few outliers (Figure 7.13).

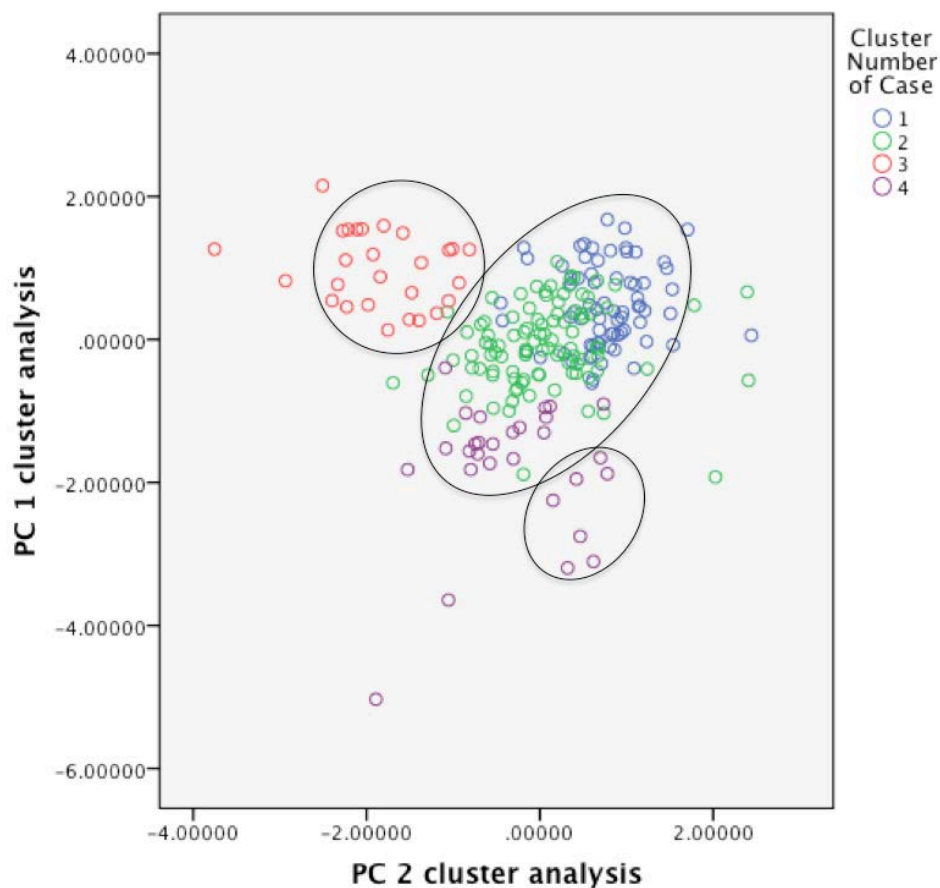


Figure 7.13 Plot using PCA scores and presuming 4 clusters showing two groups and possible other small groups. Ellipses are made artificially.

### 7.2.9 Discriminant Function Analysis for Ceramic Sherds of all Kuwait and Bahrain sites

DFA was employed as a different statistical technique to discriminate between groups and classify the samples into different production centers. It was assumed that there is a minimum of two to a maximum of six groups as performed and original log data was used for all seven elements (Nb, Th, Sr, Y, Zr, Rb, and Ba) as variables, and site names as a grouping variable. The results showed that DFA could produce three discriminant functions that can significantly group the dataset (Table 7.8). The canonical discriminant function plot showed that the ceramic sherds could be separated into two main groups, with a potential small group

Table 7.8 Loading of each variable into each discriminant function.

	Function		
	1	2	3
Ba_Log	.685	1.847	3.672
Th_Log	6.012	6.000	5.160
Rb_Log	.956	1.581	1.374
Sr_Log	5.679	8.984	4.220
Y_Log	5.973	32.642	7.001
Zr_Log	1.078	5.352	9.559
Nb_Log	4.053	18.742	6.226

(Figure 7.14). The Wilk's output showed that only two discriminant function scores are statistically significant ( $p < 0.05$ ). Thus, a scatterplot was performed using discriminant scores on the discriminant axes (DF1, DF2) to determine if those functions are able to group samples (Figure 7.15).

Ceramic potsherds were grouped into four main groups, as the PCA and cluster analysis. Those groups that formed the big cluster (Group A) come from Al-Khidr, F3 Period 3A and 3B, the Palace and Trench E from Failaka Island and from Qala'at and Temple of Barbar sites in Bahrain, with at least two overlapping samples from the Mesopotamian House. Group B consisted of samples from the Mesopotamian House on Failaka Island, with overlaps; five samples from Al-Khidr, three samples from Temple III, one sample from F3 Period 3A, one from Trench E, and F6 and F3 Period 2. Group C had eight outliers all from the F3 site Period 3B. This group appeared in the PCA plot as a potential third group and in the cluster analysis as well. Finally, a possible group D was scattered and might be clustered to consist of mixed specimens from Al-Khidr, Trench E from Failaka Island, and the Barbar Temple of Bahrain. Based on statistics, 72% of the original grouped cases were correctly classified. In addition to the four groups of potsherds, there were several outliers that appeared in the left part of the

scatterplot and between group B and C. They were from Al-Khidr, F3 and the Mesopotamian House, similar to a potential group D in the multivariate analyses of Kuwait samples.

#### 7.2.10 Principal Component Analysis for the Early Second Millennium BC Sherds from Failaka Island

The samples that were analyzed for the early second millennium BC consisted of 75 ceramic sherds from various types of early Bronze Age pottery on Failaka Island and Bahrain (Table 7.9). The aim of this analysis was to determine if there were any nonlocal ceramic potsherds on Failaka Island, particularly at the Palace of the Tell F6 site. Furthermore, I wanted to test the research question about the possibility of Failaka elites accessing far-distant items during Dilmun's expansion. Any outliers within the F6 site on Failaka Island were examined carefully to determine their provenance based on their styles and mineralogical composition under a polarizing microscope.

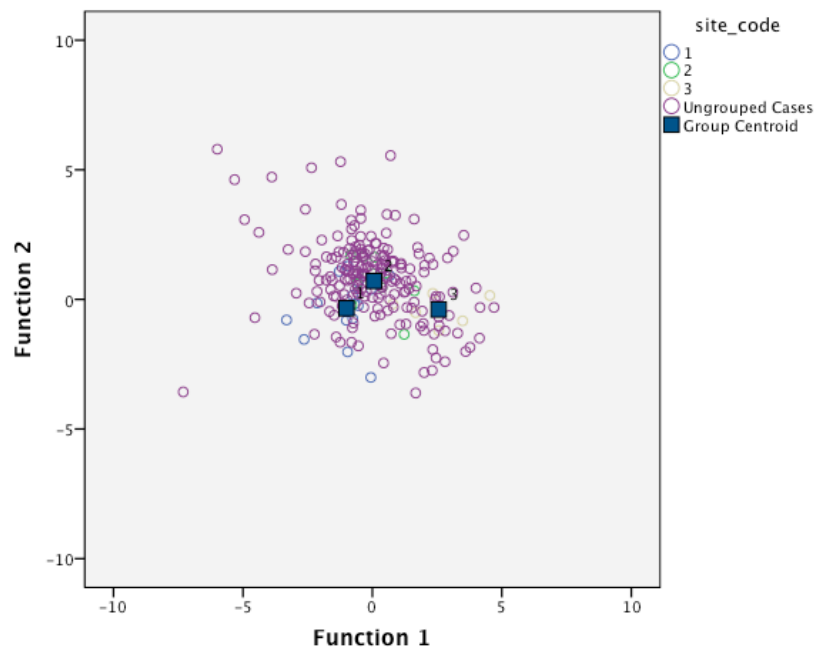


Figure 7.14 Biplot based on discriminant function showing two group (centroid 1, 2 vs. 3).



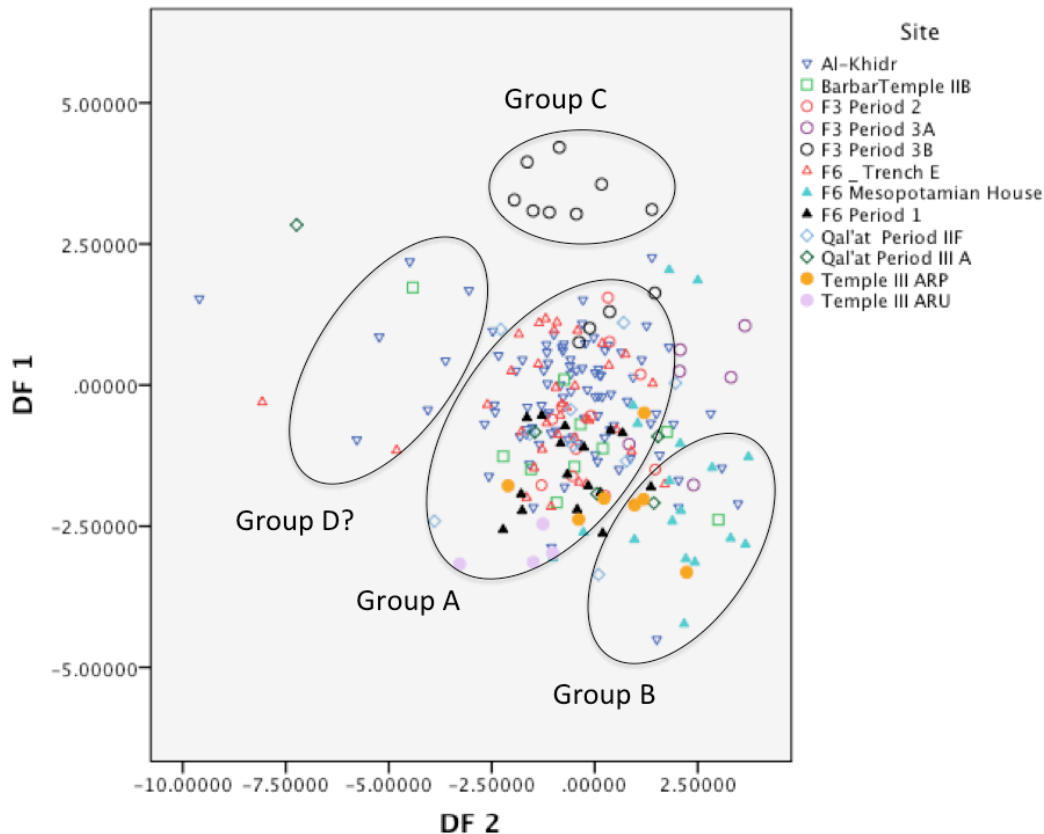


Figure 7.15 Biplot of DF 1 and 2 showing a mixed pattern of Dilmun sherds (group A), along with the Mesopotamian House (group B). Note a few potsherds from F3 clustered alone (group C). 72% correctly classified. Ellipses are made artificially.

A total of 66 potsherds were taken from the Tell F6, in the southwest of Failaka, which consists of three sites: the Palace, Trench E, and the Temple. Among the 66 sherds, a total of 16 were taken from the palace-like feature known as the Governor's Palace. The samples were taken from the earliest phase known as Failaka Period 1, ca. 1950 BC, recovered during the 1960s. A total of 34 samples were taken from a new trench (Trench E), which lies between the Governor's Palace and the Temple in Tell F6. This trench was excavated during the Kuwaiti-Danish mission of 2009 to determine if there was a connection between the palace and the temple (Højlund 2012). All ceramic potsherds selected for this study from Tell F6 were affiliated typologically with the Dilmun tradition and parallel to Failaka Period 1 in the Palace, with a few

Table 7.9 Summary of sample materials of early 2nd millennium Kuwait and Bahrain.

Site	Structure	Region	Sample Size	Phase
Tell F6	The Palace	Failaka Island,	16	Period 1
Tell F6	Trench E	Failaka Island,	34	Period 1
Tell F6	Mesopotamian House	Failaka Island,	16	Pre-Period 1
Barbar	Barbar Temple II	Bahrain	9	Period IIb
			Total 75	

unknown and unusual types found at the site. Among numerous sherds uncovered at the Mesopotamian House in F6, 16 rim and body sherds were selected and marked as a Mesopotamian House collection. In addition to Failaka Island potsherds, a total of 9 came from the Barbar Temple II in Bahrain. The samples were taken from the IIb phase that is contemporary and parallel with the earliest phase in Failaka, Period 1 (1950 BC).

As with the above multivariate analyses using SPSS, transformation of the dataset into logarithms has been performed to standardize the data. The results showed that the first three components explain 79% of the variance. A scatterplot was performed using PCA scores 2 and 3 that included Nb, Th, Sr, Y, Zr, Rb, and Ba, which previously showed their high contribution in the component matrix. The results showed two distinct groups of ceramics (Figure 7.16), while the Palace, Trench E and Barbar Temple clustered together (group A). It also showed a distinct group of samples including the Mesopotamian House with a few outliers from the Barbar Temple and Trench E (group B). There were two outliers from the Palace; noticeably one is an outlier. The PCA results showed the separation of sherd samples between and within the archaeological sites.

Table 7.10 Component matrix of each variable loading.

	Component		
	1	2	3
Sr_log	.918	.017	.145
Nb_log	.872	.233	.245
Y_log	.619	.186	.541
Rb_log	.065	.928	.094
Zr_log	.113	.726	.279
Th_log	.497	.593	.319
Ba_log	.023	.238	.907

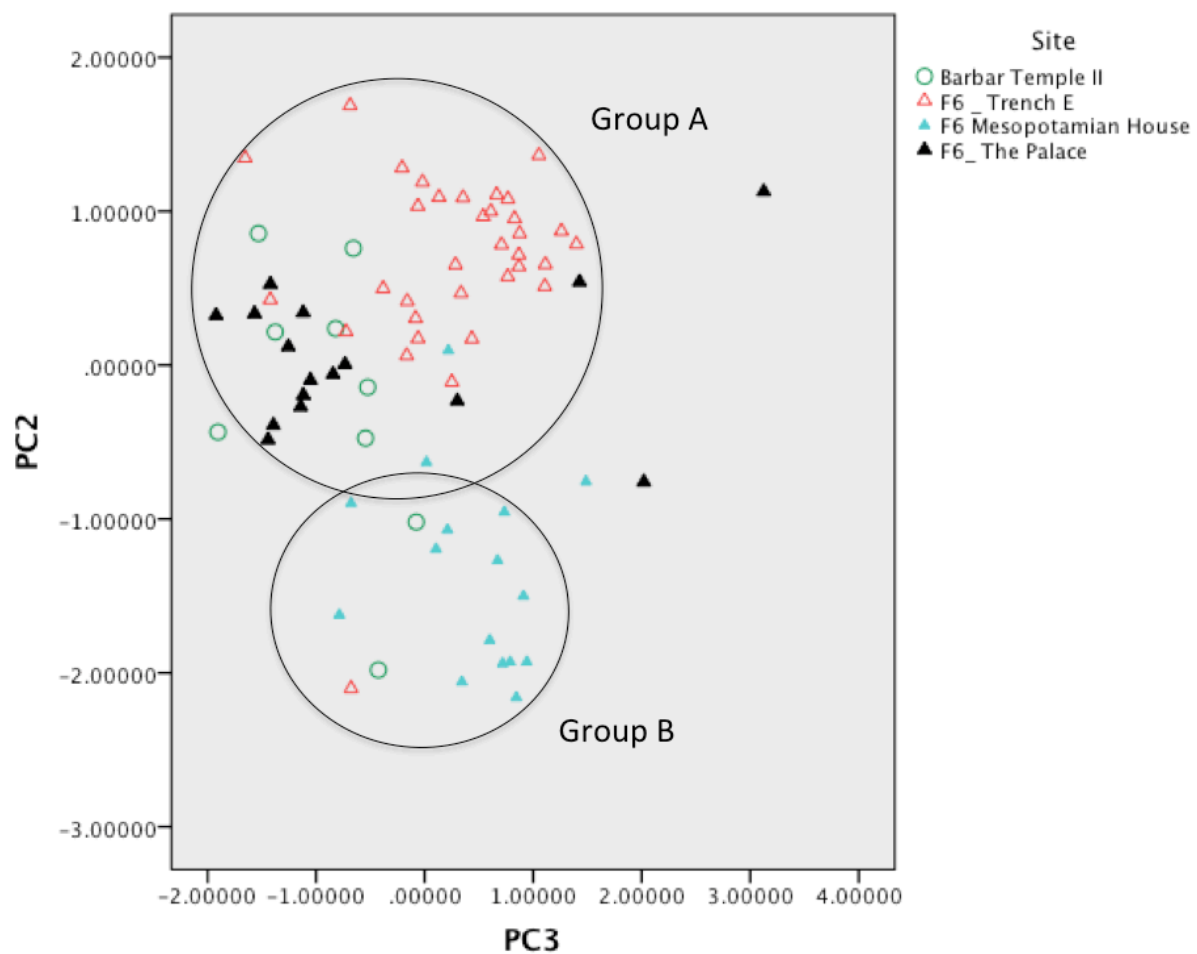


Figure 7.16 Biplot derived from PCA of 75 samples. Note the Barbar Temple II sherds overlap with the Mesopotamian House collection and outliers from F6. Ellipses are made artificially.

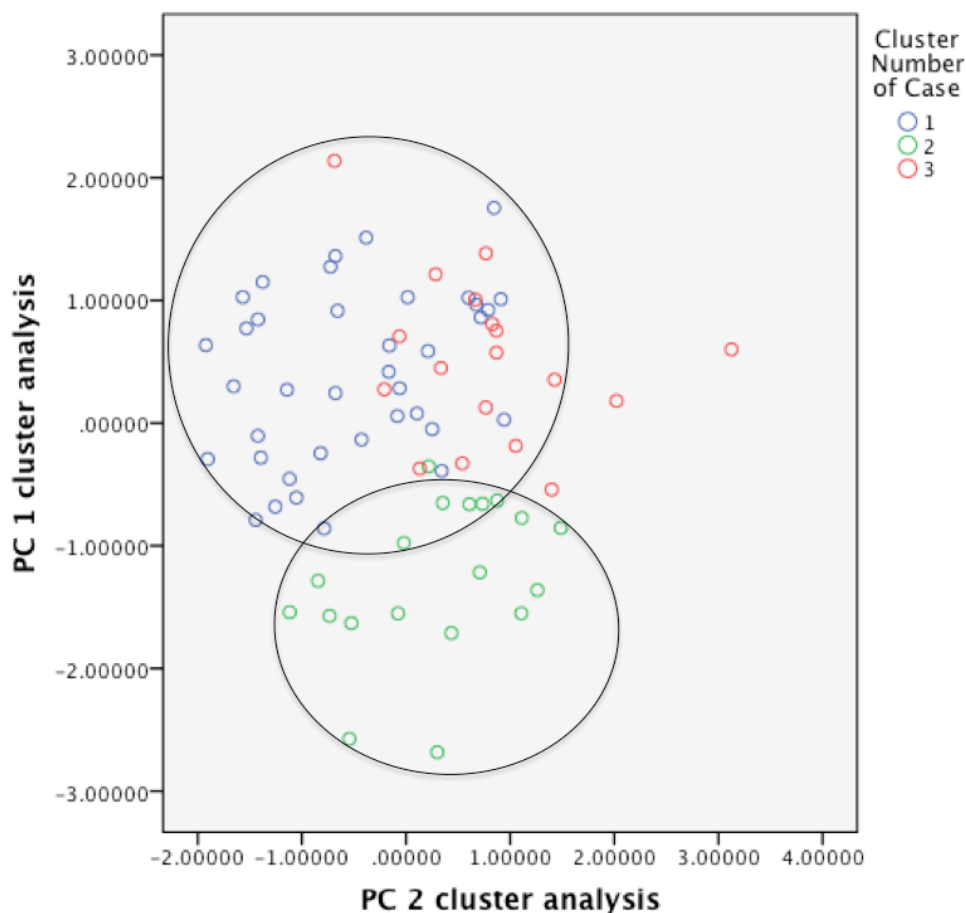


Figure 7.17 Biplot of cluster analysis using PCA scores and presuming 3 clusters, showing two distinct groups and a few outliers. Ellipses are made artificially.

### 7.2.11 Cluster Analysis of the Early Second Millennium BC Sherds from Failaka Island

The principal component analysis was followed by a cluster analysis using PCA scores, which included all 7 elements (Nb, Th, Sr, Y, Zr, Rb, and Ba), for identifying natural groupings and evaluating PCA results. K-means cluster analysis was utilized for the clustering method based on presuming three clusters to group all samples and then find clusters. The ANOVA output showed that all PCA factor scores were statistically significant ( $p < 0.05$ ), which confirmed the PCA scatterplot (Figure 6.14). A scatterplot was performed using PCA 1 and 3 to

set markers. The results showed that there were two distinct groups, with a few outliers (Figure 7.17).

#### **7.2.12 Discriminant Function Analysis of the Early Second Millennium BC Sherds from Failaka Island**

DFA was employed as a different statistical technique to discriminate between groups and classify the samples into different production centers. For DFA, the average of the groups was four as it was supposed to represent four production centers that the samples might have been made at: Dilmun, Mesopotamia, Indus Valley, and the Iranian plateau.

Original log data was used for all seven elements (Nb, Th, Sr, Y, Zr, Rb, and Ba) as variables and site names as a grouping variable. As shown in the above analyses, DFA produces a matrix of function, based on the presumed groups in order to show the contribution of each variable in the DFA. The result showed that three discriminant functions were obtained (Table 7.11). The canonical discriminant function plot showed that the ceramic sherds are separated into two main groups, with a potential small group (Figure 7.18). The Wilk's output showed that the three discriminant functions are statistically significant ( $p < 0.05$ ). Thus, a scatterplot was performed using discriminant scores on the discriminant axes (DF1, DF3) to determine if the three functions produced are significant and able to group samples (Figure 7.19).

Ceramic potsherds were sorted into two main groups. Those groups that formed the big cluster (group A) came from the Barbar Temple, the Palace, and Trench E, with one overlap from the Mesopotamian House. Group B consisted of samples from the Mesopotamian House on Failaka Island and the overlapping two samples from Trench E and the Barbar Temple of Bahrain. Group C has four outliers from the Palace site. Finally, Group D was clustered in the middle of the scatterplot that consisted of mixed specimens, one from the Barbar temple (No.

13662) and four from the Mesopotamian House on Failaka Island. This group of ceramic sherds obviously appeared in the discriminant analysis more than in the former analyses. Based on statistics, 81.3% of the original grouped cases were correctly classified.

Table 7.11 Loading of each variable into each discriminant function.

	Function		
	1	2	3
Rb_log	.955	.065	.096
Th_log	.362	.700	.054
Nb_log	.010	.442	.246
Ba_log	.062	.450	.773
Zr_log	.347	.040	.403
Y_log	.160	.279	.382
Sr_log	.079	.058	.341

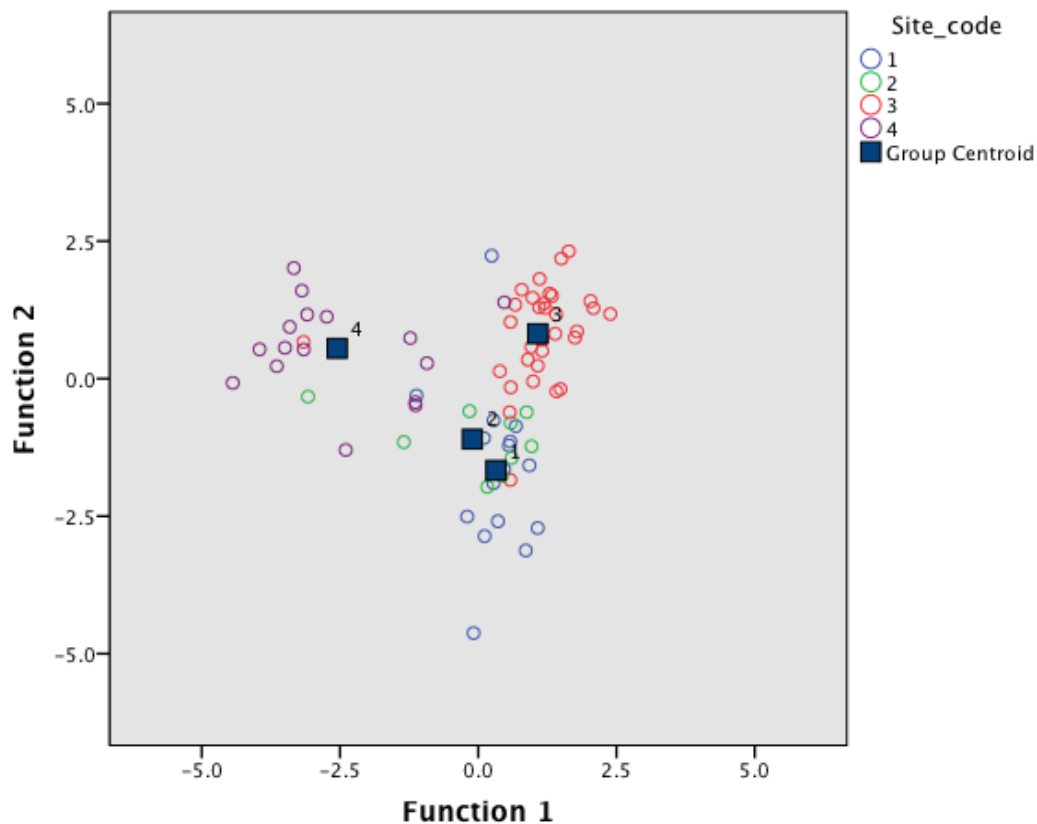


Figure 7.18 Biplot based on canonical discriminant functions showing two distinct groups and a potential third one (after Ashkanani and Tykot 2013).

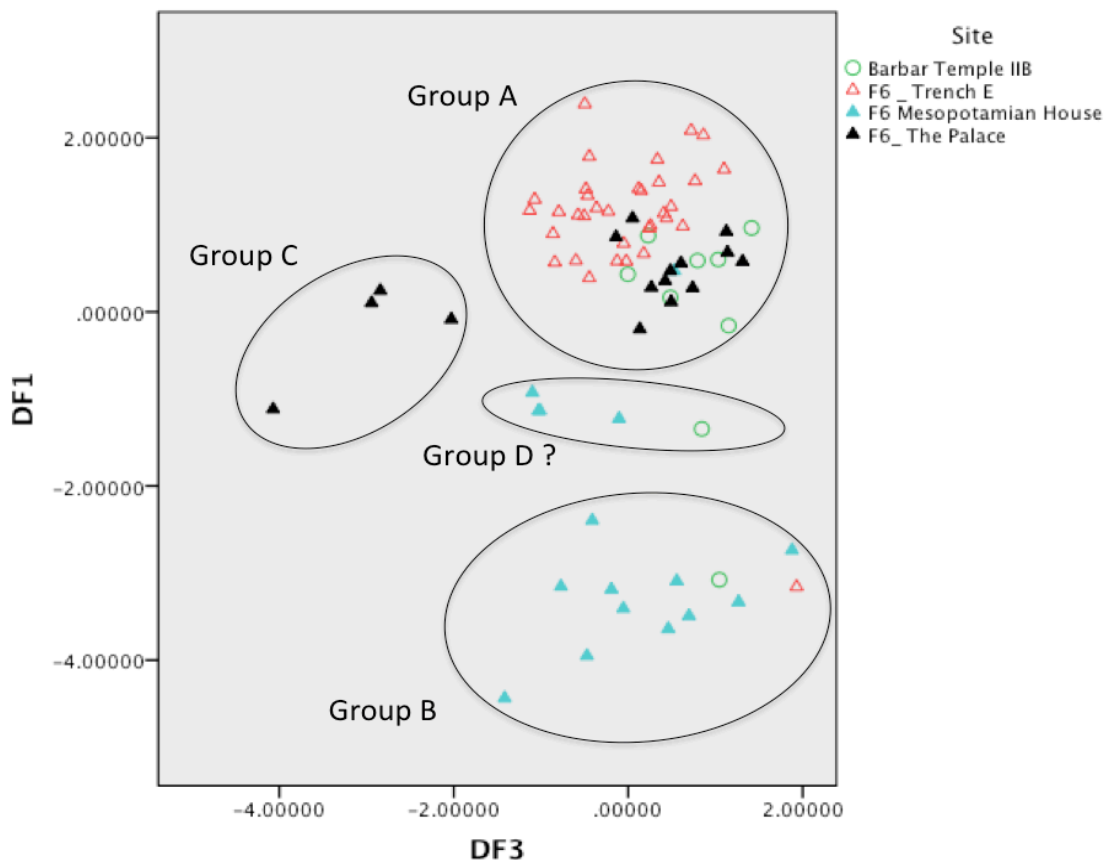


Figure 7.19 Biplot of DF 1 and 3 showing a mixed pattern of Dilmun specimens from Failaka and Bahrain sites (Group A), along with the Mesopotamian House cluster (Group B). Note that a few sherds from the Palace were combined together (Group C). Ellipses are made artificially.

### 7.3 Results from Preliminary Experiments

#### 7.3.1 Preliminary Test Results with pXRF

There were four preliminary characterization studies conducted using pXRF since summer 2010 that were held at the Laboratory for Archaeological Science at the University of South Florida. These studies were designed to use a few samples as a reference of their cultural affiliation; thus, a demarcation of an existing tradition against those presumed non-local. The limitation of pXRF has been noted, in chapter four and five, and the prerequisites that must be undertaken to avoid such was determined, the multiple shots and the selection of a flat surface.

Excluding diagnostic cooking pots, painted sherds, eroded or non-flat outer and/or inner surface was necessary for the pXRF technique to obtain reliable results. The samples were from the Harappa site in Pakistan and the Susiana site in Iran. Among a total of 304 sherds and clay samples, only 20 samples were selected for testing. A group of samples (n=10) were excluded from pXRF analysis as they had paint. The results demonstrated that samples could not be compared with other ceramics analyzed by pXRF unless similar analysis settings and calibration software were used.

The statistical analyses demonstrated a noticeable pattern in the simple scatterplots and in the multivariate statistical tests. Simple scatter plots of trace elements Rb, Sr, Nb, and Y showed the best separation between the Indus valley collection and the Gulf's samples. The results certainly showed that the Indus Valley was well clustered and separated from the Gulf's collection, including the Mesopotamian and Iranian samples. Some sub-groups within the Gulf's collection were noted in the simple scatterplots; particularly, between the Dilmun collection and the Mesopotamian House at F6 on Failaka Island, as representative of Mesopotamian Ur III ceramic sherds.

The multivariate statistics also supported the delineation of this distinct group from the Indus Valley collection. Neither multivariate statistics nor exploratory results showed any outliers within the Indus Valley group. The Mound E and Mound AB sherds were clustered rather well. The results also showed that none of the Gulf samples overlapped with the Indus group. In other words, it means that none of the Gulf's outliers, that were assumed to be of Indus origin overlapped with this collection. Samples No. 13613 and No. 13620, from the Palace at Tell F6 on Failaka Island, were identified as Harappan styled because they appeared to be hard red-clay sherds, made of very fine sand, and handmade. These sherds were clearly outliers in all



multivariate statistics. However, they did not overlap with the Harappan group. The latter suggests two possibilities: the two outliers are of Harappan origins but not produced at Mound E and Mound AB in which the Harappan pottery sherds came from; or the two outliers are not Harappan and might have been produced in southeast Arabia (Oman or UAE) or within that Mesopotamian territory.

In addition, the statistical analyses demonstrated that there is a variation between Iranian ceramic groups. The ceramic sherds, from the Susiana Plain and Tepe Farukhabad in Deh Luran, overlapped with the Mesopotamian House collection. Also, the North Susiana sherds overlapped with a group of samples from Tell F3 on Failaka that were assumed to be of Mesopotamian origin. The Susiana collection that overlapped with the Mesopotamian House sherds consisted of greenish to pale-brown jar and goblet body sherds while the North Susiana sherds were reddish-to-brown jar rims and shoulder and one goblet rim (Figure 7.20).

Finally, the multivariate tests of all samples showed that a total of 9 clay samples were outliers and do not overlap with any ceramic groups (Figure 7.21). The clay samples seem to be clustered in one group as none of them are dispersed. Only two clay samples were clustered with the major Dilmun collection. Those clay samples came from Al-Sabiya in the north of Kuwait (no. 15575) and Al-Qarn in the Eastern Province of Saudi Arabia (no. 15579). Also, there was a variation even within Kuwait clay samples as three of a total 9 clay outliers came from Kazma in the north of Kuwait and from Dilmun and Kassite walls at Tell F6 on Failaka Island. In general, the results suggest that using the clay samples, as a reference to fingerprint ceramic production centers, is unreliable.

Multivariate statistical results of all Bronze Age ceramics from Kuwait and Bahrain showed a pattern of at least three distinctive groups. The mean and standard deviation of the

noted groups are presented in (Table 7.12) Ceramic potsherds from group A are all from Dilmun sites in Kuwait (i.e. Al-Khidr, Tell F6, Tell F3) and from Bahrain sites (i.e. Barbar Temple II and NE Temple and Qala'at). The only exception was the Mesopotamian House at Tell F6 on Failaka Island, which was clustered into a separate group (B); also, most samples from the F3 site's Period 3B were another distinctive group (C). The high Rb is what partitioned Group A from B and C, while high Ba and Sr were the major factors that further distinguished Group C. This pattern of distinctive groups was noticeable in all the multivariate statistical assessments. Each group was a mixture of samples from different sites, with the exception of samples from the F3

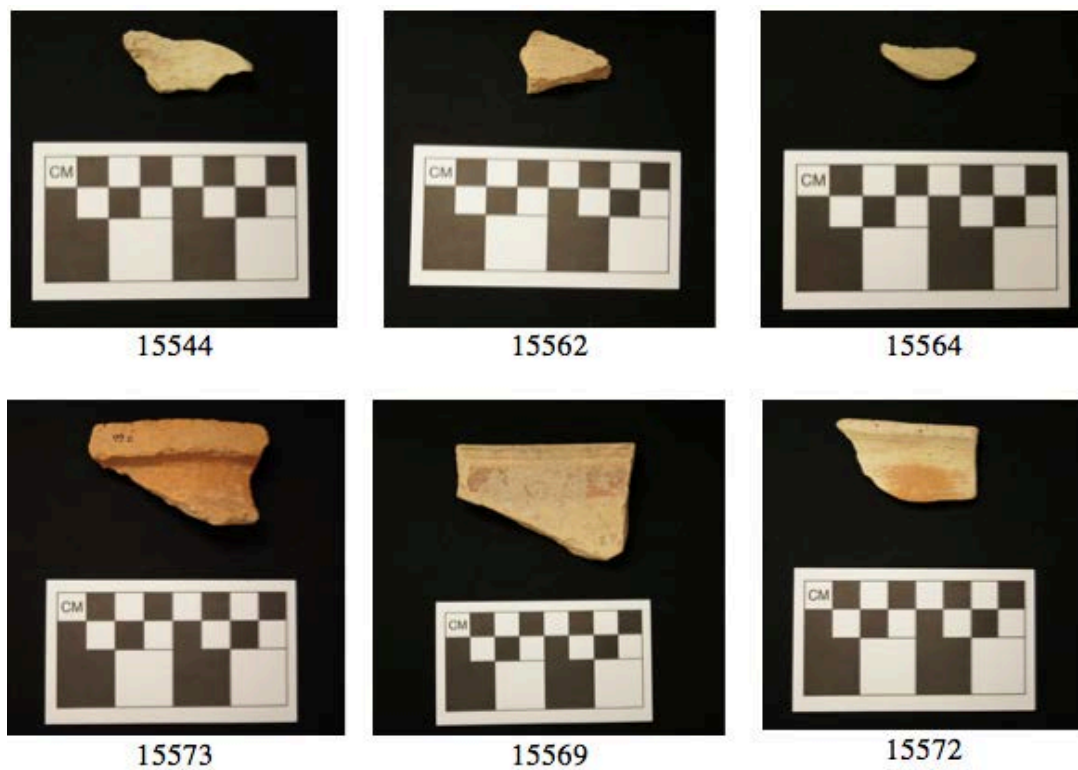


Figure 7.20 Ceramic sherds from Susiana Plain and Deh Luran (in the top) as their colors range from greenish to pale gray and N. Susiana (in the bottom) as reddish to pale brown.

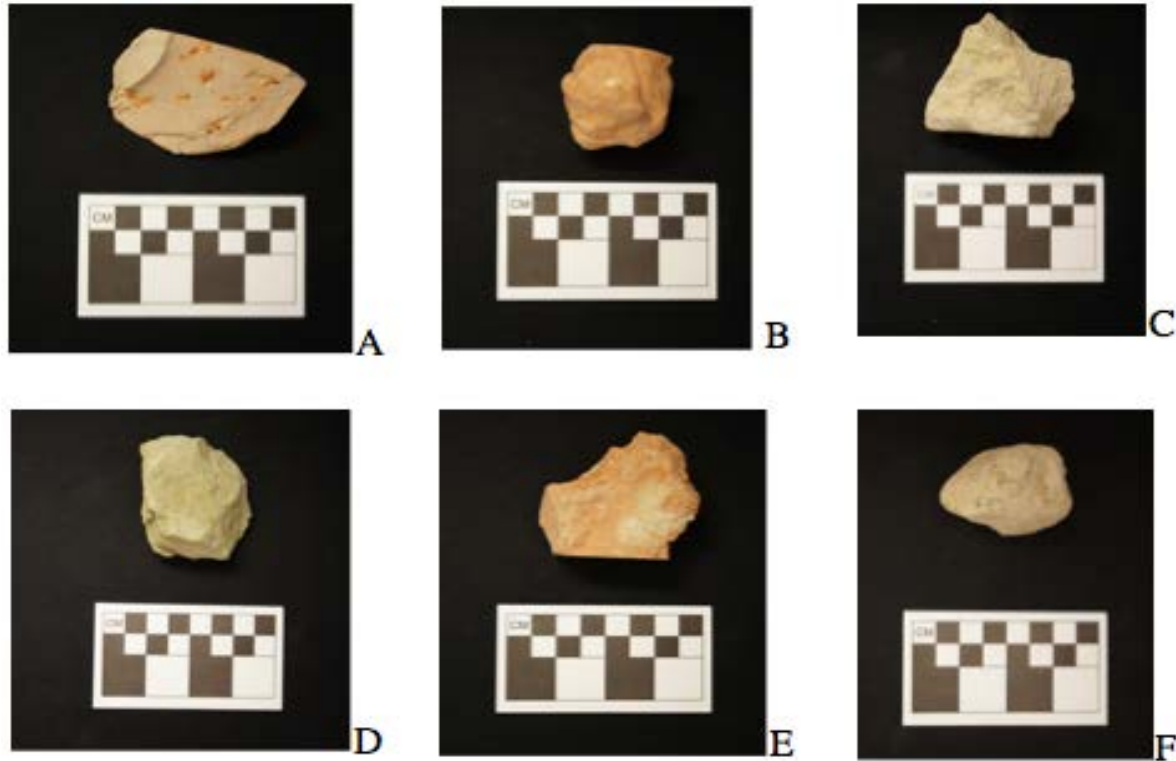


Figure 7.21 A collection of clay samples analyzed by pXRF. Clay samples A and B are the only samples clustered with the Dilmun group while the others are scattered.

Table 7.12 pXRF data summary for three distinct Bronze Age ceramic groups (ppm).

	Group A		Group B		Group C		Outlier		Iran		Harappa	
	Mean	std	Mean	std	Mean	std	Mean	std	Mean	std	Mean	std
<b>Ba</b>	2504	1058	2493	468	3429	463	4055	1644	2891	552	1104	196
<b>Th</b>	6	2	5	1	4	1	7	3	5	1	15	2
<b>Rb</b>	72	18	30	11	60	17	69	33	44	15	164	12
<b>Sr</b>	742	295	716	466	2560	889	1504	2207	1112	515	120	29
<b>Y</b>	28	3	32	3	22	3	24	10	28	4	37	5
<b>Zr</b>	144	20	119	18	144	20	167	43	115	17	160	13
<b>Nb</b>	46	3	47	3	35	6	48	7	45	3	54	1

site (group C) that stood alone, with no overlapping samples. In order to support the three hypothesized groups for Dilmun and Mesopotamian collection, MANOVA was performed to support if the dependent variables (chemical elements) can distinguish between the three groups.

The Pillai's Trace result shows a significant value of zero which confirms that the groups are statistically different.

### **7.3.2 Results from Preliminary Experiment with Petrographic Thin Sectioning**

The preliminary results of petrographic analysis of Dilmun ceramic sherds showed that the temper type was quartz-rich sand, temper grains and were the major temper inclusions (Stremtan et al. 2014; Ownby, Appendix C). Interestingly, the petrographic analysis of 25 samples (in Appendix C) showed that the percentage of inclusions in the ceramic samples ranged between 5% and 30%, with the exception of one sample at 40% (No. 13676). Thus, the method of taking multiple shots for each sherd successfully answered the potentially poor representativeness of the sampling strategy. Based on the optical activity of some inclusions, the preliminary results also showed that there was a variation in the firing temperature, 700-850° C. Some heterogeneity among Dilmun samples was observed. The heterogeneity of Dilmun samples was due to the multiple clay sources as iron-rich silty micaceous and calcareous clay types were used. There was no synchronic and diachronic correlation between each clay type and archaeological site or chronological phase.

## **CHAPTER EIGHT: DISCUSSION**

### **8.1 Introduction**

This chapter describes the results of pXRF analysis on the ceramic dataset and discusses in detail the chemical groups noticed. It focuses on the relationship between each compositional group and pottery type and chronological phase. It has been assumed that the pXRF is able to distinguish between Bronze Age potsherds from Kuwait and Bahrain based on the trace elements. Also, the research interests aim to discover if there is any variation within Dilmun pottery, as representative of two or more workshops on Failaka and in Bahrain; also, if there is uniformity in the clay sources used. Therefore, the petrographic analysis results of 25 samples are discussed in this chapter to assess the pXRF data and to examine the level of raw materials and standardization.

First, there is a description of the patterning of each pXRF group: Group A, B, C and outliers. For each group, there is a detailed discussion about the pottery type, the archaeological site, the chronological phase, and a direct interpretation related its historical context is presented. Next, the results of the petrographic thin section analysis that was performed on 25 ceramic samples from Kuwait and Bahrain are presented. There is a detailed description of each sample and grouping (See Appendix C). In this chapter, the discussion is centered on the relationship between each petrographic group and its cultural influence.

There are two main groups noticed representing Dilmun and Mesopotamian groups. Within the Dilmun collection, there are three subgroups (A.1, A.2, A.3) that are related to the

different clay used and temper preparation. The outliers are also discussed. The potential provenance of each compositional group is discussed by explaining the geophysical features of Kuwait, Bahrain, Southeastern Arabia and the Indus Valley in which the outliers had possibly come from. Finally, there is a look at how the various ceramic compositional groups are related to cultural and historical variables

## **8.2 Ceramic Grouping by pXRF**

### **8.2.1 pXRF Group A**

Group A is comprised of wares from all the major Bronze Age sites on Failaka Island and from Bahrain. This group has a large amount of ceramic artifacts comprised of large red-ridged jars, brown, and yellowish- brown vessels as well as red slipped and whitish to pale brown slipped. They have the ridged, reddish, slipped feature typical for the Bronze Age Dilmun or Barbar pottery type. Interestingly, they are grouped together based on elemental composition obtained by pXRF. This type of pottery can be further divided stylistically into identifiable sub-groups based on technological production, color, grain size, and hardness as described in chapter 2. All four Dilmun fabric types (A-, B-, C-, D-ware) are clustered in this group. Also, the C-ware wheel-made which is restricted to rippled vessels such as sample No. 13642 are clustered with the handmade samples. The latter is a wheel-made greenish to yellowish, thin-sherd rippled vessel, known as rippled shoulder, Højlund's 1987 type 47 (Flemming Højlund, personal communication 2010). Within those ware types in Group A, there is the E-ware type that is associated with Mesopotamian tradition. Two E-ware samples from Qala'at Period IIIA (nos. 13689 and 13690) are clustered with group A and were presumed as of the Mesopotamian tradition. In terms of fabric treatment and style, they are not similar to the Barbar samples that

come from the same site and period (no. 13691 and no. 13692). The color is uniform as a yellow and reddish core that corresponds to Bibby's caramel color (Højlund 1987:105). They are rippled rims that have multiple grooves (type 67C) and multiple grooves on a giant rim (type 73A) with all associated with the Mesopotamian tradition (Højlund 1987). On the other hand, the Barbar sherds from Qala' at Period IIIA are wheel made, reddish yellow (13692) and uncommon greenish (13691), tempered with little lime particles as associated with the C-ware type.

Within group A, there is a sample (no. 15163) that came from the Mesopotamian House of the Tell F6 site that overlaps repetitively with the Barbar ceramic group. Based on its red color, slip, and incised lines, it is diagnostic of Period 3A ceramics on Failaka (Højlund, personal communication). The Period 3A (1720-1550 BC) piece could have been deposited later into the Mesopotamian House feature during the rebuilding or restoring of the Temple on top of the Mesopotamian house structure.

In terms of function-space perspective, the Barbar ceramic artifacts in this research could be made from a single clay source based on pXRF results. All identical Barbar sherds that have slip, ridge, or are attributed to local ceramic production are obviously made from the same clay source and/or temper materials suggesting a uniformity of land-use from the early second millennium BC. There is no discernable separation between Failaka Island ceramic assemblages and the Bahrain collection. Group A comprises all local Barbar sherds even those with greenish outer (sample no. 13691) or greenish gray (e.g. nos. 14229, 14242, 14307). Also, no separation is apparent between the red slipped sherd and the yellowish-pale brown Barbar sherds. Moreover, the same inference can be made regarding the nature of the manufacturing of wares; there is no chemical difference between hand-made and wheel-made Barbar pottery or between some forms of pottery versus others (e.g. storage jar vs. vessel). Thus, the mixture of all Barbar ceramic

forms and types from Failaka Island and Bahrain in one distinct group presents the homogeneity of Barbar ceramic recipes. Previously, it was hypothesized that the recipe difference may be noticeable between Failaka Island sites and Bahrain ones or specific sites; thus, possibly denoting status, associations of artisans, and the value of ceramic type or form.

Failaka Island has multi-component sites with stratigraphic levels that represent different phases, zones, and chronological periods. Testing for homogeneity of ceramic recipes on Failaka Island was one of the major goals of this inquiry. According to pXRF results assessed by multivariate analyses, it is unlikely that there is heterogeneity between each chronological period or phase in the collection from Failaka Island and Bahrain. There is no difference in terms of the chemical recipe between Failaka Period 1 versus Barbar Temple II in the early second millennium BC or between Failaka Period 3A versus Qala'at Period IIF in ca. 1730-1550 BC. Thus, the potters used the same clay and temper materials relatively and there was no change or more access to clay sources through time.

Changing clay sources within each chronological period or phase or accessing more clay sources can be used to suggest more than one pattern of land use, such as procurement of raw materials and the possible transport of clay or vessel. The data suggests that there was a consistent use of particular clay sources for Barbar ceramic production. Furthermore, it implies the geological features of Kuwait and Bahrain are so similar, that the testing could not distinguish two or more production centers. Also, it is important to note that the clay choice is consistent during the Dilmun periods, possibly inferring potter's preference.

The decisions of using single clay is consistent and parallel to the development of Barbar pottery technology in early the City II or Barbar Culture of the early second millennium. The development of Barbar pottery shapes as red-ridge style became dominant (92%) (Hojlund



1994a,b) in the early second millennium BC and the new Barbar ware types, that came later, had no relationship to any change in clay choice. Also the introduction of turntable pottery in Period IIb as an indicator of a gradual shift from household to professional craft production is not related to the professional potter's decision of clay choice. The choice of raw materials is uniform whatever the technique and ceramic type are.

### **8.2.2 pXRF Group B**

Ceramic potsherds of group B are comprised of samples from six archaeological sites on Failaka Island and Bahrain. These potsherds were wheel-made and highly tempered with fine material. The sand particles are seldom seen, while the colors range from pale brownish and pale greenish to light gray (Figure 8.1). Some sherds have a surface of fine texture and smooth clay, while some have straw impressions (G-ware type). The G-ware group was known for being wheel-made, except for the giant storage vessels, and belongs to the Mesopotamian tradition (Højlund 1987:106).

The majority of the group B samples came from the Mesopotamian House structure, the lowest level of the Temple at F6 site on Failaka Island as a reference group to represent Mesopotamian clay. It represents the Third Dynasty of Ur or Ur III occupation horizon (2100-2000 BC) that pre-dates the establishment of the Dilmun colony or transit point on Failaka Island (Flemming Højlund, personal communication 2011). The Mesopotamian House collection has a variety of types. For instance one rim sherd (no. 15159) has two ribs or ridged rim (Figure 8.1A) corresponding to Ur III Type 1 vessels that have been uncovered at Hamad Town burials in Bahrain (Laursen 2011). This type is distinctive as it is heart-shaped with a point-end base. The rim typically represents the largest diameter of the vessel that has two or three rounded ribs

(Laursen 2011:34). Their colors are creamy white, pale brown, and pale greenish with some fine straw impression. This vessel type also has been found at Qala'at of Bahrain, Højlund's Type M11, and as a rounded-pointed base that was found at Ur, Nippur, and Umm al-Hafriyat in Mesopotamia (Højlund 1994a:105). This type has been found at Ali Mounds and Hamad Town in Bahrain, the Eastern Province in Saudi Arabia, and recent excavation on Failaka Island in Kuwait as a remnant of the Akkadian to Ur III periods (Højlund 1994a, 2012). One sherd (no. 15161) of group B represents Højlund's Type M22 (Figure 8.1B) for which the shoulder has several horizontal ribs ca. 2 cm apart (Højlund 1994a:108). One sample has an incised ridge (no. 15171). This type of shoulder is found at Nippur and Umm al-Hafriyat as characteristic of Late Akkadian and Ur III. Also, a ceramic sherd of Højlund Type M20 (no. 15165) has perforation representing group B (1994a:108). Based on PCA and cluster analysis, the red sherds from the Mesopotamian House are clustered with group B (Figure 8.1C).

Following a chronological order from the earliest site and phase, within group B, one sample (no. 15137) came from Trench E on Failaka Island that represents the early Dilmun occupation level, 2000-1900 BC (Figure 8.1D). It was assumed to be an imported sherd (Flemming Højlund, personal communication 2011). Features like its pale brownish to green color and homogenous hard texture along with the quantitative results support its association with the Mesopotamian tradition. Also, one sample (no. 13661), which came from the Barbar Temple II of Bahrain, overlaps repetitively with the Mesopotamian sherds (Figure 8.1F). It was assumed to be of the Barbar tradition, but it falls within the Mesopotamian group. Texturally speaking, it is wheel-made and has light green to gray color on the outer and inner surfaces. This product might have come to Bahrain during the Isin-Larsa dynasty in Mesopotamia that ruled the south portion from 2000 to 1760 BC. In particular, it may have arrived between 1950 and

1850 BC as the sherd represents Barbar Temple, Phase IIb. Following the next phase, no sample could be tied to the later phase on Failaka – Period 2 – in Group B. One sample (no. 13671) from the NE Temple, dated to period ARP that is parallel to Failaka Period 2, is included in Group B (Figure 8.1K). Despite it being typed as a Barbar C-ware, greenish sherd, it fell repetitively within Group B. The Barbar greenish sherds are dominated in NE Temple Period ARP as the other four samples, but sample no. 13671 is an exception.

Following the next phase, also one sample from Tell F3 on Failaka Period 3A is included in this group. Based on PCA, sample no. 13646 is clustered within group B (Figure 8.1E). It is a big storage jar body sherd, wheel made, straw tempered and a grayish green color representing type G-ware which is attributed to Mesopotamian tradition pottery. Among 91 ceramic sherds from Al-Khidr on Failaka Island, only 10 ceramic potsherds are included in Group B. They range from pale brownish to greenish gray thin body sherds. Among 10 potsherds, a total of 5 samples are straw-tempered greenish gray sherds and handmade representing the G-ware type (Figure 8.1E, G, I). One sample represents the E-ware type that is wheel-made and has straw impression that is less obvious on surface (Figure 8.1H).

Also, a greenish gray vessel base is represented in Group B that came from Al-Khidr (Figure 8.1J). Two thin greenish sherd samples are also clustered with Group B, and their inner surfaces have black slip due to cooking or bitumen applied. Finally, one well-fired hard ware is also clustered but it was assumed as a late period/Islamic ware. Details of chronology verification of Al-Khidr ceramics are still in processing by the Kuwaiti-Slovak Archaeological Mission. However, Benediková (2010) outlined out the major typology in the collection from 2004-2006, assigned as the Barbar and Mesopotamian traditions, with a few perhaps of Eastern tradition from UAE and Oman (Benediková 2010:184). Chronologically speaking, Al-Khidr

ceramic assemblages can be dated to Failaka Period 2 (Qala'at IIB-IIF), Failaka Period 3A (Qala'at IIF-IIIA) and Kassite Failaka periods 3B-4A (Qala'at IIIA-IIIB), with a few traces of the earliest phase Failaka Period 1 (Benediková 2010:184). Based on pXRF results, the Al-Khidr nonlocal sherds that are clustered with Group B could be dated to pre-Kassite Failaka periods. Based on the choice of ceramic recipe and the clay source, one could use the results to date these materials. The Group B collection could represent pre-Kassite Failaka periods, such as Failaka and Barbar Temple.

The similarity in chemical composition between one of the samples from Trench E and the Barbar Temple sherds with greenish sherds from the Mesopotamian House suggests the use of the same raw material. The Mesopotamian House sherds from the Tell F6 site are useful as a group reference for Mesopotamian geology, or at least for Mesopotamian origin. The Mesopotamian House sherds infer the Ur III expansion in the Arabian Gulf. It is documented that under the Ur III rulers, Mesopotamian merchants established a connection with suppliers of copper, particularly with Magan/Oman. The claim of Ur-Namma (2113-2095 BC) referred to the establishment of trade with Magan during his reign, copper in exchange for textiles (Astour 2002:101).

Numbers of Type 1 of Ur III vessels discovered in Dilmun mounds in Bahrain support the long-distance trade and exchange between Ur III and Magan that might have been placed by highly organized institutions (Laursen 2011). The distribution of restriction of Ur III pottery in the Arabian Gulf could indicate: 1) specialized potters that affiliated to the temple and palace economies of the Ur III rulers (Wright 1998) who in turn controlled long-distance trade and exchange; and 2) probably the luxury items dispatched in those standardized quality vessels were preferred in the Arabian Gulf (Laursen 2011:44).

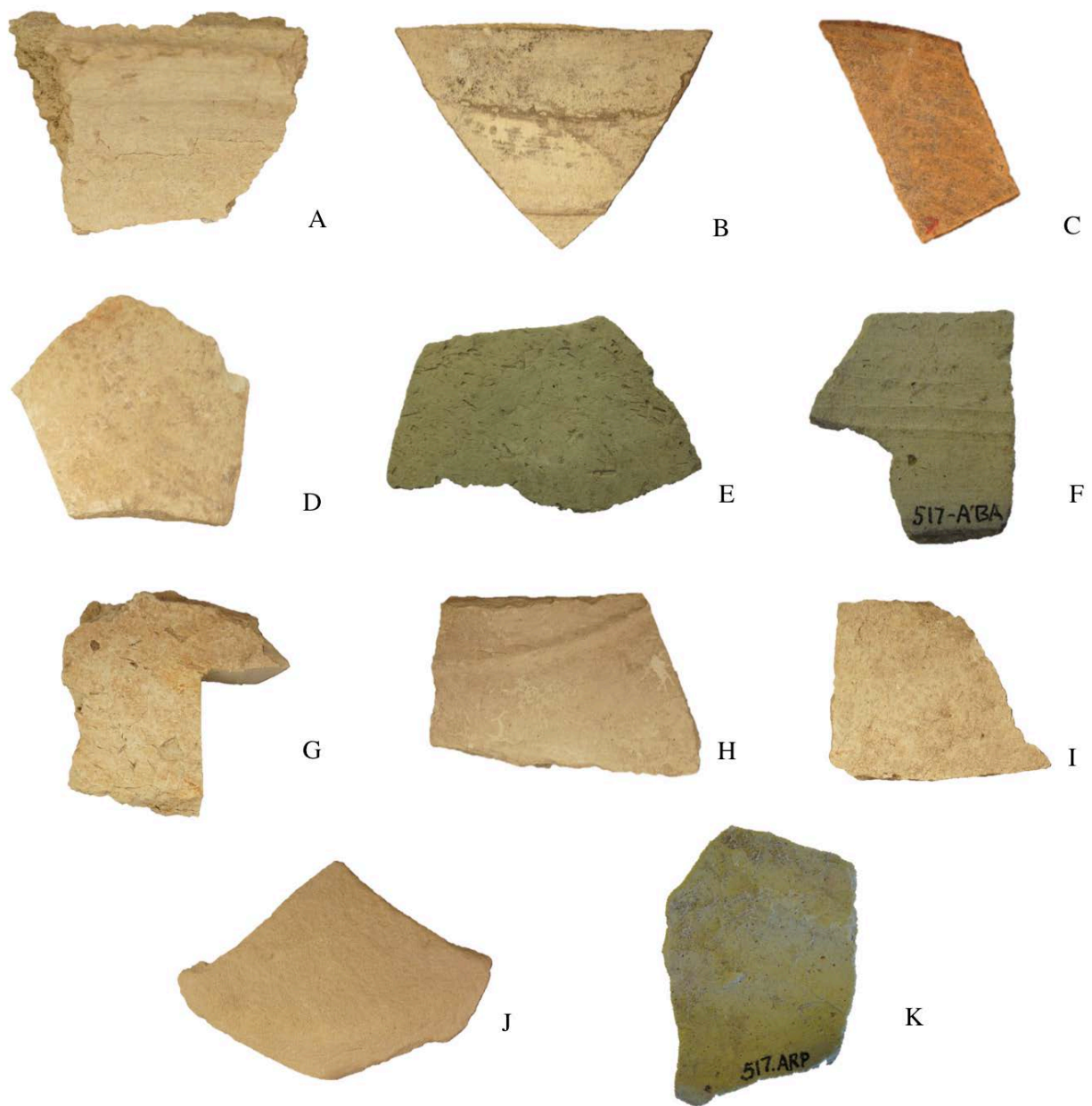


Figure 8.1 Group B consisting of Mesopotamian tradition sherds, from six archaeological sites, as their colors range from pale greenish, brownish, to pale gray.

With this recent discovery of the Mesopotamian structure and the support of this chemical analysis, Failaka may have been under control of Ur III authorities; one of those harbors and refueling centers along the trading routes, during the end of the third millennium

BC. The presence of Ur III on Failaka is also supported by the early discovery of a Ur III cylinder seal in the bottom of trench F2 at Tell F6. The inscription indicates the name of the seal owner, “*Namhani son of Inimku*”, with both names familiar in Ur, Nippur, and Lagash during Ur III (Potts 1990:286). The discovery of this cylinder seal in 1964 did not become fully contextualized with other Ur III finds on Failaka until the discovery of a Mesopotamian House structure in 2009 (Kjaerum 1983:154; Højlund 2012).

Regarding a sherd from F6 Trench E Period 1, Mesopotamian type pottery forms a minor component in Failaka F6 and F3 Period 1 and 2, relative to Barbar pottery (Højlund 1987:111). The context of Mesopotamian types belongs to Ur III, Isin-Larsa, and the Early Old Babylonian periods, with the best parallel in the Old Babylonian periods. Unlike Failaka, the Mesopotamian sherds seemed uncommon in the two Barbar Temple II phases Temple IIa and IIb (Højlund 2003:225-32) that are parallel to Failaka Period 1. At Qala’at of Bahrain, the Mesopotamian types were reduced to 6% in the Qala’at Period Ia and disappeared in Period IIb (Højlund 1994b:470-72). However, this light green sherd from Barbar Temple IIb, which was assumed to be a Barbar wheel type, could be an exception. The petrographic thin section can be supportive in understanding the manufacturing technique in Barbar Temple period IIb in which the Barbar wheel-made pottery has become slightly more common (Højlund 1994b:472).

The F3 Period 3A sherd from Group B represents the leap in Mesopotamian types on Failaka during period 3A (ca. 1730-1550 BC.). In this period, the Mesopotamian types became common and comprise 50%, making significant change of the ceramic finds on Failaka Island. Some types are continuous of Isin-Larsa period but the best dating comes from type 61A that has a parallel at Isin Tell during the Old Babylonia. This vessel at Isin contained a cuneiform tablet from the Hammurabi’s reign, ca. 1752 BC (Højlund 1987:158).

Despite the Isin-Larsa and Old Babylonian relations with Failaka still being intangible, the Old Babylonian texts provide an insight on the importance of religion in Failaka. Several texts inscribed on fragments, cylinder seals, and ceramic rims provide a divine scene and names associated with Dilmun religion. Inscriptions, scratched on the red-ridged rim, mentions the divine name Inzak and inscribed steatite sherds mention Inzak temple, with both uncovered at the F3 sites (Potts 1990:286-87). More than nine inscriptions on cuneiform tablets mention the Dilmun deity “Inzak” and the Babylonian deity “Enki”, and lord of Dilmun – Inzak. This religion-based interaction and body of active merchants could explain the presence and coexistence of Babylonian and Dilmunite Failaka.

### **8.2.3 pXRF Group C**

The pXRF group C consists of 8 ceramic sherds that came from Tell F3 period 3B and one sample from Qala’at of Bahrain period IIIA. Among 12 samples from Tell F3 period 3B, a total of 8 are consistently and repetitively clustered as a separated group, while one sample from Qala’at (no. 13693) overlaps with this group in PCA and cluster analysis but not in DFA. Interestingly, all Tell F3 period 3B samples in this group including the Qala’at sample are attributed to Mesopotamian tradition wheel made. Five samples from tell F3 period 3B and one sample from Qala’at IIIA are categorized as E-ware type (Figure 8.2). According to Højlund, sherds of this type are well-fired and non-oxidization gray can be seen in the core. It is tempered with medium to fine sand and some straw has been added (no. 13656) but less than in G-ware that clearly is attributed to Mesopotamian pottery. E-ware sherds usually refer to the production of wheel-made vessels as in this group with the exception of giant jars and almost all of Mesopotamian tradition (Højlund 1987). The color ranges from pale brown, reddish yellow to

pink. It has a smooth surface due to either fine slip applied or firing effect (Højlund 1987). Some of this ware type could have grooves as in ceramic sample no. 13648. It has three to eleven grooves on the shoulder and upper belly and stylistically is attributed as type 97 of Mesopotamian tradition by Højlund's standard (1987:95).

A total of three samples from group C do not belong to the E-ware type. They also come from the Tell F3 period 3B, but are attributed to different types. For instance, sample no. 13656 is a Mesopotamian splayed-neck vessel with a light greenish to brownish fine outer surface. It is a wheel-made ware that belongs to the G-ware type. This type is a well-fired, hard ware and tempered with coarse organic material (straw impression) in both the inner and outer surfaces (Højlund 1987).

This type is always a wheel-made unslipped vessel that belongs to the Mesopotamian tradition. The parallel of this splayed-neck has been found as small and large goblets in Old Babylonian Nippur (Højlund 1987). This sample was assumed to be a non-Mesopotamian as this sherd might have been parallel to Elam and Susa style (Flemming Højlund, personal communication 2010). The chemical analysis confirms its similarity to the Mesopotamian style as it falls in with the F3 Mesopotamian sherds. The overlapping of this presumed Iranian sample with the Mesopotamian group confirms the usefulness of using Iranian samples as a reference for Iran geology. Thus, more analysis such as petrographic thin section is required to determine if any possible differences in term of texture and raw materials between Mesopotamian and Elamite tradition.



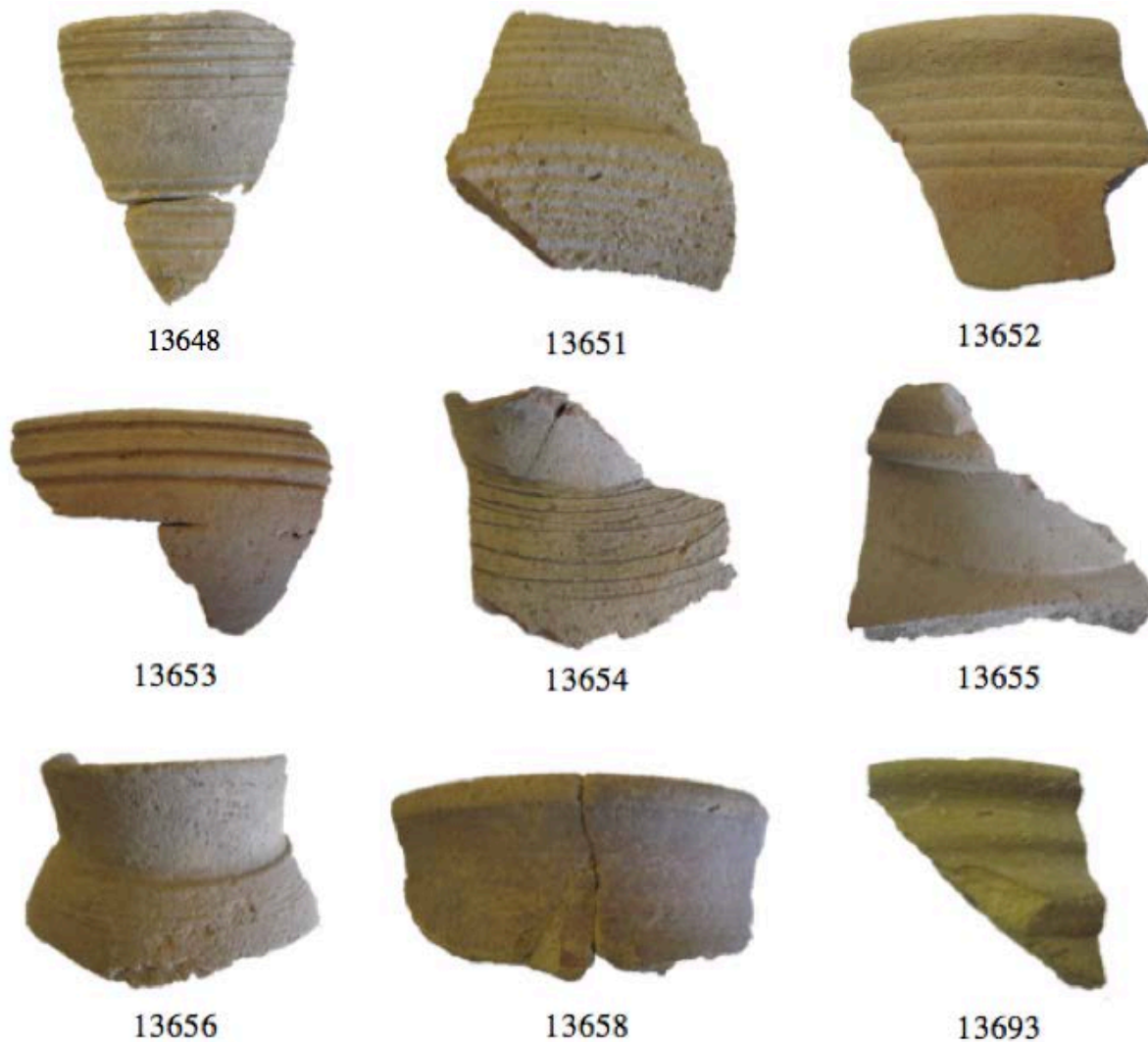


Figure 8.2 All nine samples clustered with group C resemble the Mesopotamian shape. Note that the Qala'at sherd (no. 13693) is more greenish.

Sample no. 13654 from the F3 site Period 3B is also clustered in group C. It has a rippled outer and D-ware type that is well-fired and medium-tempered with sand. Despite this ware type having been attributed to the Barbar tradition, the chemical analysis and statistical results confirm its Mesopotamian origin as it falls repetitively within the group C collection, with F3 Mesopotamian sherds. As it is noted from the rim setting being off in relation to the shoulder, this sherd is identical to Barbar tradition type D ware, that is handmade, rounded edge, with

horizontal incised lines and yellowish-brown slip. This Dilmun style sherd that has a Mesopotamian chemical characterization would suggest the imitation of Dilmun pottery in the mid-second millennium BC. This imitation might have been produced within late Old Babylonian/early Kassite territory, before its dissemination to the Dilmun site at Tell F3. Otherwise, it is suggested that the raw materials were imported to Dilmun during the Kassite or late Old Babylonian period. The repetitive fall within group C excludes any possibility of being attributed by analytical error as it comes from the same site and same period when the Kassites conquered Old Babylonia (ca. 1590 BC) and occupied Dilmun in the fifteenth century BC.

Finally, sample no. 13693, dated to Qala'at's Period IIIA, is also clustered within the group C collection in DF analysis. It is also a wheel-made rim sherd, but more greenish than other sherds in this group. The archaeological site of Qala'at in period IIIA is also contemporary with Failaka's Tell F3 site period 3B and its samples are clustered in this group. Based on its style as of Mesopotamian origin and the DF analysis, it is associated closely with the late Old Babylonian/early Kassite collection. The three-ribbed jar rim of no. 13693 is identical to Qala'at or City IIIA that has wares of Mesopotamian origin and shape (Højlund 1986:220). It is also close to Failaka Period 3B, known as type 56, as the most common type of the period (Højlund 1987:121). In general, it has been assumed that Qala'at IIIA Mesopotamian shape collections are not typical of Mesopotamian pottery, but similar with some respect to wheel-made Barbar types of an earlier period IIF (Højlund 1986:220-222). However, the chemical analysis confirms its clay being distinct from the Dilmun collection of group A and even from the Mesopotamian Ur III collection of group B.

Geoffrey Bibby (1969:136) describes this collection from his excavation of Qala'at in 1956 as thick, sand-tempered, "caramel ware". In general, the pottery from F3 period 3B is made

up of Mesopotamian shapes that consist of 60% of the total period's pottery while 90% in the Palace or Tell F6 (Højlund 1987:121). The pale brown or caramel pottery marks the beginning of the 3B period. Period 3B forms are bowl rims with multiple grooves, knob-footed goblets, and triple-ribbed jar rims. The most common fabric in period 3B is E-ware, but not much straw temper as in G-ware. In period 3B, C- and D-ware also occurred, but with Barbar tradition (Højlund 1987:121)

Even though the archaeological evidence and stratigraphy mark a clear break in the ceramic assemblage, the origin of the (Potts 1990:270) ceramic collection of Period 3B is still debatable between late Old Babylonian and early Kassite, a Dark Age in Mesopotamia (Højlund 1986:220). In 1595 BC, the Hittites conquered the Old Babylonian Empire and the documentation of the whole next century is lacking (Larsen 1983:50). During this century, the First Sealand controlled the region until 1415 BC, when the Kassite groups, who originated from Zagros Mountains, moved southward to seize Babylon and Nippur. A documentation of the first two centuries of Kassite rule in Mesopotamia is sparse and their occupation of Dilmun in Bahrain and Kuwait appears to have been uneventful (Larsen 1983:50). The so-called Dark Age is noticeable after the collapse of old Babylonian Empire. The power shift in Mesopotamia makes it difficult to affiliate Period 3B and Qala'at IIIA ceramic assemblages to any specific Mesopotamian type.

The definite Kassite-Dilmun relationship can be understood from letters and cuneiform tablets. Two letters, dated to the reign of Burnaburiash II (ca. 1370 BC), refer to an administrative issue between a provincial official in Dilmun to his superiors in Mesopotamia. Cuneiform tablets have been recovered from Kassite period buildings in Bahrain that were fired around 1370-1340 BC, according to radiocarbon analysis of charred date remains (Larsen

1983:51). Also, a dedication on a stele at Qala'at supports the end of the Golden Age of Dilmun or City II (Qala'at II) and the dominance of Kassites. It refers to the Kassite king Burnaburiash II and commemorates construction or restoration of a sanctuary and palace (Vine 1993:33). All this evidence supporting Kassite control over Dilmun is not parallel with the F3 Period 3B or Qala'at IIIA that extended from 1550 to 1450 BC. However, marking a new phase of 3B is certainly clear by the appearance of an entire structure (temple terrace) at F3 that was built over four period 3A houses, Kassite and Mitanni cylinder seals found on the F3 temple's floor, and three inscriptions found on Failaka that mention a temple called the *e-g a l* which is suggested to be a name of the temple (Højlund 1987:135; Kjaerum 1983:81; Potts 1990:270-271).

In Bahrain, the early Kassite phase began at the Qala'at site when Bibby noticed the presence of a diagnostic ceramic fabric named as "caramel ware". This caramel-colored pottery had been noticed in the surface collection during the Oriental Institute's Diyala Basin Archaeological Survey (Potts 1990:299). In the 1962 campaign, an architectural feature of the Kassite type with caramel pottery was uncovered, measuring 22.5m by 17.5 m, and described as a massive wall of a cut stone building (Bibby 1969:345). The evidence of Kassite occupation in Bahrain and Failaka Island is much more datable in the later period (Qala'at III B and Failaka Period 4A) in which letters and cuneiform tablets mention Dilmun of Bahrain as part of Kassite domination (Rice 1994:115-118).

The presence of Kassites in the Dilmun realm in the mid second millennium BC is marked as a dramatic shift in the ancient history of the Arabian Gulf. It witnesses the Kassite domination over the Gulf and their complete control over Dilmun. With a parallel to two expansionary episodes at the same period in Nubia by the Egyptian New Kingdom rulers and in Fars of Iran by Elamites, Kassite presence in the Gulf is characterized as colonialism. Edens

(1986:200-03) points out the political control of Dilmun by Kassite Babylonia in 1400 BC as some form of colonialism on the island. The latter is based on some textual evidence from Babylonia and Nippur which mention the governor of Tilmun/Dilmun, dated to perhaps 1420-1410 BC.

Furthermore, this colonial presence extended to Qatar, where Kassite ceramics were found and resemble Kassite assemblages at Failaka and Babylon (Edens 1968:203). The shell midden at the Khor site in Qatar can be a definite sign of the purpose of Kassite expansion in the Gulf. Edens (1987, 1994) argued that the relationship between Mesopotamian Kassite and Qatar was based on trade-of-port exchange. The Kassites had control on purple-dye production, processed from the shellfish *Thais*, for coloring textiles. The Kassite control on Bahrain was to insure the route of purple-dye from Dilmun to Mesopotamia, whether controlling private activities (sailors) or having institutional dominance. However, the Kassite pottery at Khor Ile-Sud in Qatar proposed such an institutional context of a purple dye industry in the Gulf that the occupants of the site were associated with Babylonia (Edens 1986:203). Therefore, Edens (1986) argued that trade was important or the major motive for Kassite colonialism in the first half of the second millennium.

The Kassite-Dilmun relationship was based on controlling the production center(s) of commodities, the extraction of surplus, and labor obligation which all incorporated Dilmun and the Gulf into the Kassite administrative and colonial structure (Edens 1968). The direct extraction of agricultural surplus from perhaps land granted to the institution or officials by a class of labor suggests some relation of production. The warehousing of dates and date juice pressing evidence at the Qala'at site, from period IIIA, infer some scale of the incorporation of the Dilmun into the Kassite Empire (Edens 1968; Rice 1994).

Determining the scale of production of Kassite ceramics within the Dilmun realm could be addressed by comparing the group C assemblages with those from Babylonia and Nippur as a significant scope for future studies. The sand-tempered Kassite ceramic assemblage that is in contrast to the straw-tempered Babylonian ceramics suggests non-Babylonian manufacture of the Bahrain Kassite pottery (Edens 1986) or that a new manufacturing technique occurred in Babylonia during the Kassite period. This probably explains why the group C assemblage does not overlap with Group B, which includes Ur III and Babylonian straw-tempered ceramic samples. Therefore, obtaining more ceramic samples from Nippur and other Kassite centers could be useful as a reference collection for non-destructive analysis.

The use of petrographic thin sectioning supports the identification of the clay minerals and rock fragments of wares and the subsequent matching to the geological landscape of Mesopotamia. This step is important not only to fingerprint ceramic production centers but also to answer some questions related to the imitation of Kassite pottery in Dilmun territory. It was argued that local potters started, during the Kassite period, to imitate the shape of Mesopotamian pottery on Bahrain. Moreover, some Mesopotamian potters may have come to Dilmun (Vine 1993:33). If this was the case, in parallel to the pXRF results, it means that the local potters may have made Kassite-tradition pottery using local clay but different from those used for Group A ceramics. In other words, a specific pottery type requires a certain clay resource. This could explain why the presumed Dilmun-tradition ceramic sherd no. 13654 is clustered with group C. Obtaining more samples from Nippur and other Kassite sites in Mesopotamia as well as running comparative pXRF and petrographic analyses can shed light on the scale of ceramic production during the Kassite period.

#### 8.2.4 Outliers

Among 293 ceramic potsherds, a total of 10 ceramic samples did not cluster within either group A, B or C (Figure 8.2.). Some of these samples were noted as being outliers or as a distinct group, called Group D in the DFA plot. However, those 10 ceramic samples seem scattered without any pattern of a distinct group, except in the DF analysis of early Dilmun sites from Failaka and Bahrain. They came from four sites: a total of three samples came from the Palace in Tell F6 Period 1, one sample came from Tell F3, five samples came from Al-Khidr and one ceramic sherd came from North Susiana in Iran. In terms of ceramic texture, the outlier samples are divided into two types, well-fired hard clay and porous non-flat surfaces. Their colors vary but red and reddish brown are common along with two whitish ceramic fragments.

It was assumed that sample no. 13613 from the F6 site (Figure 8.3A) is unknown or had Harappan origin (Flemming Højlund, personal communication 2010). It is wheel-made, well-fired, fine sand-tempered, and has a very smooth outer surface. The small size of the sherd makes it hard to identify its cultural affiliation. Sample no. 13618 from F6 Period 1 is also reddish wheel-made and has a flat surface (Figure 8.3B). It was assumed as Barbar tradition based on the red slip or paint on the outer surface (Flemming Højlund, personal communication 2010). Therefore, the outer surface was excluded from pXRF analysis but the inner value is still very high relative to Barbar ceramic sherds of F6. Also, sample no. 13620 is another outlier from F6 Period 1 (Figure 8.3C). Similar to the other two F6 samples, it was assumed as atypical and might have Harappan origin (Flemming Højlund, personal communication 2010). It has a gray slip on red ware that has fine sand temper and was well fired.

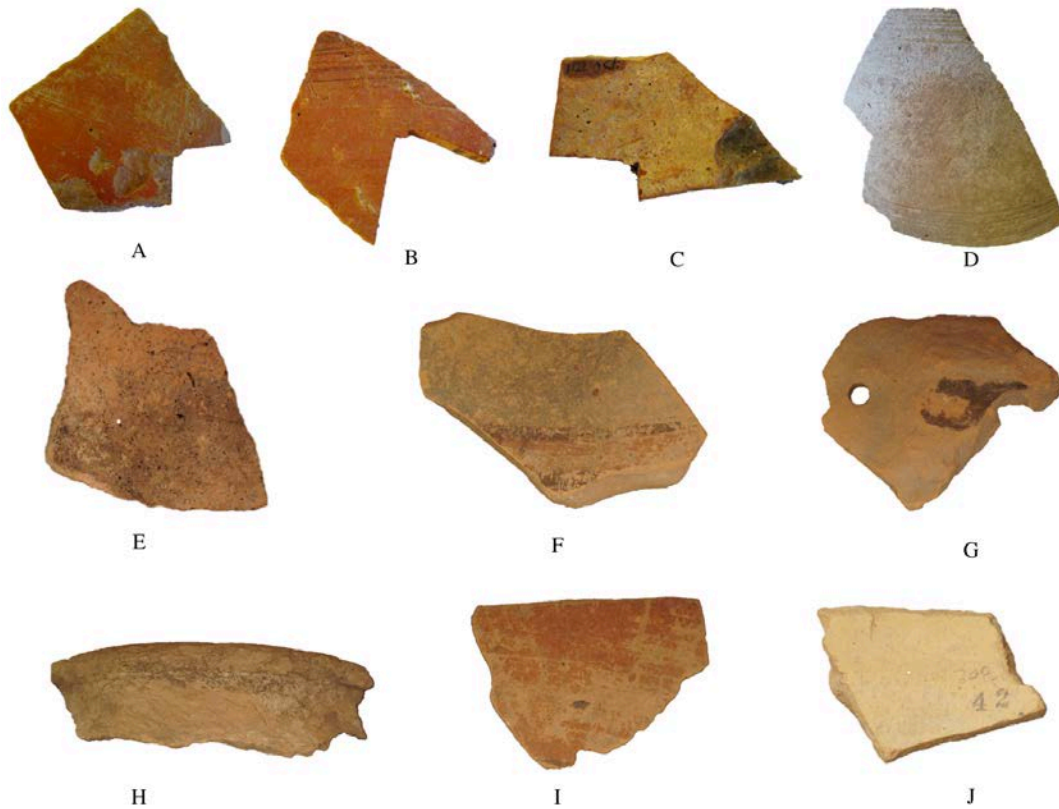


Figure 8.3 Samples as outliers from F6, F3, and Al-Khidr in Kuwait and N. Susiana in Iran – scattered outside the three main pXRF groups.

Potentially, these three ceramic potsherds could be the basis for a future study regarding the circulation of nonlocal pottery within Dilmun, particularly on Failaka Island in the early second millennium BC. The restriction of finding non-local pottery at F6, which is considered a governmental structure, could support one of the research arguments about the access of Failaka elites to exotic and long-distance items. Also, it would support the idea of a limited distribution of local, wheel-made, painted pottery (possibly sample no. 13618?) in the early Dilmun phase on Failaka Island.

One sample that came from Tell F3 Period 3B is an outlier. It has been duly noted that 8 of 12 samples from F3 Period 3B were clustered in Group C, representing the “caramel pottery” of the Kassite period. Sample no. 13650 is also assumed as a Mesopotamian tradition that is



wheel-made and had a rippled outer surface (Figure 8.3D). This ceramic sherd represents Mesopotamian Type 97 (Højlund 1987:95). It has two bunches three to eleven grooves placed on the shoulder. The color of this sherd is lighter than the Group C collection, perhaps of more whitish clay. According to Flemming Højlund (personal communication 2010) this vessel could have been imported from a big city in Mesopotamia. This type of vessel also was found on Bahrain with thin rims dated to Qala'at III that is parallel to this vessel (Højlund 1987:95). Being an outlier and separated from Group C, this draws another possibility of importing pottery from multiple Mesopotamian cities during the Kassite period. Again, obtaining more samples from several Kassite cities and sites in Mesopotamia would help in tracking the flow of Mesopotamian ceramics to Dilmun territories under Kassite control.

Outliers from Al-Khidr are divided into two groups based on their texture. Three samples (nos. 14285, 14289, 14293) are porous and non-flat or flaky reddish brown body sherd and rim (Figure 8.3E, G, H). They are assigned as local tradition Bronze Age pottery. It was recommended to exclude non-flat samples as the X-ray scatters due to the surface. However, those samples seemed less porous and flaky than the excluded ones. The flaked surface contributes to some errors and less precision. This error was noticeable with the flaked obsidian samples with the coefficient of variation (CV) of powdered samples being below the CV values of the flaked samples for Fe and Zr (Davis et al. 2011). Thus, those samples could be a case of the analytical error that is related to surface typography.

The other Al-Khidr outlier samples are very fine and hard wares. Sample no. 14270 (Figure 8.3F) is wheel-made, fine sand tempered, and has smooth outer and inner surfaces. It has two black horizontal lines on a light reddish-brown fine ware, and a reddish paint/slip between the two black lines. It was assumed to be as Eastern Tradition ware (Benediková 2010, Figure

136C). The red back set between black lines (polychrome decoration) is also attributed to the Eastern tradition pottery found at Qala'at of Bahrain. It is assigned as Type E7 that represents large vessels, red bands between two stripes and hard fired tempered reddish-brown fine ware (Højlund 1994a:121).

Sample no. 14308 has also similar surface treatment to sample 14270 as it has a very smooth outer surface, and is of well-fired hard clay (Figure 8.3I). It has brownish red slip on the outer surface while it seems not to have been wheel-made. It is hard to identify the pottery tradition but it seems very close to as Eastern Tradition Type 10E(e) and/or Type 10E(i) which both are characteristic of red slip on fine red or light brown ware (Højlund 1994a:125-27). Both types are referenced from Mohenjo-Daro and Harappa in Pakistan and found in Gujarat sites on the northwest coast of India (Jonathan Kenoyer personal communication, 2014). The very smooth dense surface sherd decorated with black bands has been found on Failaka in Period 1 context as well as a little from Qala'at which is assigned as Harappan (Højlund 1987:101). The sample no. 14270 is resembled to Jhukar pottery in Chanhudaro as decorated with two colors, red and black, and Jhukar pottery from Amri (Højlund 1994a:122). No Jhukar pottery has been identified from Mohenjo Daro even though an early attempt was made to affiliate a Harappan vessel with Jhukar style (Dales and Kenoyer 1986:59).

It is worthy to notice that samples from Mohenjo Daro, Amri, Lothal, and Jhukar are not included in this study. Neither of the presumed Eastern Tradition sherds (nos. 14270 and 14308) were clustered with Harappan ceramics. Mohenjo Daro is located south of Harappa, roughly 680 km (425 mi) while others are far down close to the Arabian Sea (e.g. from Lothal 1,550 km/970 mi). This suggests some possibility of chemical variation within the Indus Valley. A chemical analysis of bangles, siliceous ceramic stoneware, was carried out using INAA in term of

constructing a chemical database of Mohenjo Daro and Harappa stoneware and its distribution (Dales 1991). The stoneware bangles of the Indus are highly associated with the major sites of Harappa and Mohenjo Daro as luxurious artifacts with a unique social function. Also, the results show that there are two defined chemical groups of bangles, each attributed to Harappa and Mohenjo Daro (Blackman and Vidale 1992). This study supports the unidirectional movement of bangles and a possession of bangles technology as well as a chemical variation within the Harappan cities, particularly in Pakistan.

Furthermore, the latter variation between Harappa and Mohenjo Daro's chemical components was also noticed in the studying of black-slipped jars that have been found in Oman. They are a good indication of the interaction between the Indus Valley and the Eastern Arabian–Oman Peninsula during the second half of the third millennium BC. Black-Slipped jars were analyzed by INAA and compared to stoneware bangles from Harappa and Mohenjo Daro (Méry and Blackman 1995). The results showed that the jars seem likely to fall in with the Mohenjo Daro daggers more so than Harappan clay bangles. To test whether there is a possible relationship and identify the production center of those outliers, only sample no. 14270 was subjected for petrographic thin section analysis. The red and black geometric style also has a parallel in Failaka. The French excavations at Tell F6 have uncovered several body sherds with painted bands on fine dark red clay and assumed to be from a context of Failaka periods 1-2 (Calvet and Pic 1986:56 fig. 22:80 and 80bis; Højlund 1994a:123). Thus, it is not unexpected to see Indus pottery in the Gulf that came from other cities along the river or Indus coast.

Finally, one outlier (no. 15568) came from the North Susiana in Iran (Figure 8.3J). The outer surface has horizontal straight and curved lines in dark paint that occurred on a variety of bowls and jars from the Early Dynastic phase in the Deh Luran plain (Carter and Wright 2010

fig. 3.1f; Wright 1981:111 fig.56M). The monochrome decorative outer painted surface was excluded from pXRF analysis but the inner was not which seems white slip was applied. The other Early Dynastic sherd is clustered with other Proto Elamite sherds from N. Susiana for which their colors range from red, brown to pale brown. This outlier has very high Sr and Zr relative to the other N. Susiana samples. This outlier occurred either due to the different slip material used for the inner surface that was obtained from nonlocal reddish clay, which was used to make this pottery; or it was made out of Khuzestan with local decoration. This sherd dates to the Early Dynastic phase (2900-2300 BC), which was marked by an intense competition between regional states.

During the early phase of this period, some stylistic relations with Pusht-i Kuh in Luristan, Iran and the Mesopotamian Diyala area occurred in the Deh Luran sites, leading to a closer relationship with Susiana and southern Iran beginning ca. 2550 BC (Wright 2010:83). Settlement patterns and ceramic artifacts from Diyala in the later fourth and early third millennium indicate an attempt by Diyala inhabitants to gain access to the trade routes of raw materials from Iran (Bravo 2013). This interaction is also marked by influxes of Mesopotamian Diyala painted ware and local painted pottery that has a mixture of elements from the Deh Luran province. This economic exploitation, with the emergence of regional elite in Luristan, might have allowed potters to import different materials to decorate their pottery and show their improved products.

In general, the hypothetical group defined based on pXRF show that the Bronze Age ceramic artifacts could be at least clustered in three defined groups. Dilmun pottery including all ware types and chronological phases, is clustered in one distinct compositional group. This observation is important to verify whether Dilmun pottery was made from the same single local

basic clay or various sources that could be related to a specific ware type. Based on the pXRF and the statistical analyses, this group came a single type of clay was used in the workshop that is sand-tempered manifest of Barbar tradition pottery. In terms of technique type, the majority of Dilmun hand-made pottery has exactly the same composition as the wheel-made, suggesting a preference for the Dilmun potters through the second millennium BC to use a specific clay source for a certain ware type and style.

It is important to remember that this uniformity of using a single type of clay is applied only to those ceramic sherds included in this study. The special Dilmun burial jars, which seem to have been used for burial offerings, are not included. Also, Barbar pottery from other Dilmun settlements and burial complexes such as Saar, Madinat Hamad, Diraz, Ali and Najabiyah is not included in this study. This specific compositional group is the pattern of pottery sherds analyzed from three Dilmun sites on Failaka Island and three Dilmun sites in Bahrain. It is suggested to carry out petrographic thin section on those green Barbar and presumed Mesopotamian sherds that fell within the Dilmun group. It is interesting to determine if the sherd color may have no use for sourcing. The Dilmun group comprises all typical Barbar red, brown and yellow sherds, and some presumed Mesopotamian yellow and green sherds (Qala'at IIIA and Al-Khidr). Again, it seems there is no difference in terms of chemical composition between red and green local pottery using this particular filter and analysis settings.

The Mesopotamian House collection clearly seems useful as a reference group of Mesopotamian clay. Even though they might be restricted to the Ur III recipe choice and exclude the vast types of clay in Mesopotamia, it was very helpful to verify the presumed nonlocal ceramic potsherds found within Dilmun sites. Moreover, it was a good reference to fingerprint what was presumed greenish Dilmun sherd as for the NE Temple (No. 13671) and Qala'at Period

IIF (No. 13686). It is interesting the five of seven samples from the NE Temple are assigned as greenish local sherds, which have reddish inner surfaces. Among them only one sherd, which is completely green in and out, is clustered repetitively with the Mesopotamian group. This draws to the preference of Dilmun potters to use green-like clay with the beginning of phase Barbar Temple III ca. 1850 BC. Interestingly this preference of using non-red clay does not appear as a distinct chemical compositional group; they all overlap with the typical Barbar pottery. The NE Temple ARP is parallel to Failaka Period 2 and it has very few Mesopotamian pottery types (Højlund 1987:115) with an increase of Mesopotamian influence (copper, steatite vessels) particularly on Failaka Island (Højlund 1994b:474). This increase is associated with the movement and rise of Amorite tribes in Mesopotamian who ruled the region (Isin-Larsa) and made a connection with Dilmun. The texts excavated at Ur provide a glimpse into the trade between Ur and Dilmun during Isin-Larsa and Old Babylonia times. In the texts are lists of small quantities of ivory, copper, and wooden objects with a label of “*sa kaskal Tilmun*”, ‘from an expedition to Tilmun’ (Potts 1990:220). During the Northeast Temple ARP, a text from Ur mentions *e-tilmun-na*, or Dilmun temple at Ur built for Innin by Warad-Sin who reigned ca. 1834-1823 BC (Potts 1990:221). This single sherd could be an indicator of movement of raw materials or Dilmun potter to Ur or Babylonia during the Isin-Larsa. In general, obtaining samples from the Mesopotamian House is very efficient to determine the presumed Mesopotamian potsherds.

The break of clay type within Mesopotamian is noticed with the third compositional group that represents the Kassite ceramic potsherds. It is clearly evident of using a different recipe for Kassite ceramics by the mid second millennium BC. The overlap of one sample from Qala’at IIIA with Failaka Kassite assemblages support the usefulness of using a variety of

ceramic potsherds from different sites and chronological phases to fingerprint inter-site pottery and determine the choice of raw materials and decision of potters. Using a color and manufacture technique as the criteria of cultural affinity seems not enough as was noticeable in the Kassite pXRF group. The greenish sherd from Qala'at IIIA fell with the "caramel ware" from Failaka while those presumed Qala'at caramel wares are not (nos. 13689, 13690). Also, a Mesopotamian sherd from F3 Period 3B was assumed as a local made imitation of the Mesopotamian style (Type 97) but it falls within the chemical composition range of the Kassite assemblage. It is worth carrying out more analyses in the future on those presumed Kassite potsherds that fall within the Dilmun group (nos. 13689, 13690). Without carrying out more analyses (e.g. petrographic analysis in parallel to pXRF) it is difficult to draw a conclusion about the Kassite potter's workshop in Dilmun.

The Kassite pottery is the dominant pottery type in Failaka period 3B and Qala'at IIIA. It is the period of strong Mesopotamian influence of material culture in Dilmun territory. This influence is supported by the fact that Dilmun was a Kassite province that was ruled by a Kassite governor particularly in the late fourteenth century BC. Some limestone blocks, which never had been seen in the Arabian Gulf but in Mesopotamia, were faced walls of Qala'at as well as Mesopotamian mud-bricks during period IIIA (Højlund 1994b:475). Burial mounds at al Hajjar, Madinat Hamad, and al Maqsha suggest a gradual change with the Kassite period – Qala'at/City III (Højlund 1989; Lombard 1999b:124).

Textual evidence supports the extensive Kassite-Dilmun relationship in the second half of the second millennium BC. A letter to the Kassite Babylonia governor was sent by the incumbent governor of Dilmun, Ili-ippasra who sent his daughter to school in Nippur (Rice 1994:115) and shows Kassite domination over Dilmun. There is a cylinder seal in the British museum which has

remained unpublished which mentions the seal owner, Ubalisu-Marduk, who held an office under a King Kurigalzu, who bore the viceroy of Dilmun (Reade 1986:334). Even though these texts are dated to the later Kassite phase (Failaka 4A and Qala'at III B) which succeeded Failaka period 3B, the Kassites took advantage to secure the southern territory by expanding to the Arabia Gulf. Their interest in Dilmun is evident during Kastiliashu II ca.1490 BC (Lombard 1999b:122) whose reign was contemporary with Failaka 3B. Even though some arguments make the Kassite-Dilmun relationship and Babylonian expansion as economic-based exploitation (to secure lapis lazuli and trade routes) rather than part of the Babylonian political structure (Olijdam 1997; Oppenheim 1954:16), the material culture from Failaka and Bahrain attest to the extensive presence of Kassites in Dilmun.

Using this comparative sampling strategy is very efficient in terms of providing a better understanding of the production centers, without being destructive. This strategy was effective and the comparison between different sites and different chronological phases over the second millennium BC was possible. However, the group reference seems not applicable for the clay samples that are not overlapping with the ceramic artifices. This observation could be based on the change of the ceramic recipe after firing or due to deposition, giving a different chemical characterization away from the raw materials. Also, the temper added along with the clay paste that was averaged might have a rule to exclude clay samples from the local ceramics group. This would encourage more experimental studies in the future to compare between the same clay before and after firing. INAA was carried out on the ancient stoneware bangle samples and was compared to a single modern bangles replica made by J.M. Kenoyer using clay from the Ravi river bed near Harappa (Dales 1991:68). The results show that the potter used the same raw material. However, the quantity and quality of temper materials used in the ancient stoneware



bangles that make the modern clay overlap with the ancient bangle samples must be noticed. Using different filter settings to obtain more elements in pXRF is also suggested to understand the contribution of various elements in the fingerprinting of clay and ceramics. The recent settings used here do not measure silicon (Si) that can play a role in balancing compositional groups. A recent study by Tykot and colleagues (2013) used a new pXRF perspective analysis in combining two different settings to analyze ceramic and clay samples from northern Florida. The first setting is similar to this research while the other setting is able to obtain Si, Al, K, Ca, and Ti. This is highly recommend in the future to run different settings on the same clay and potsherd samples as well as thin-section analysis on clay to determine the homogeneity. In conclusion, the pXRF is able to separate between and within sites in Kuwait and Bahrain and conclude that a single type of clay was used in producing Barbar tradition pottery in the second millennium BC.

### **8.3 Petrographic Thin Section Results**

Petrographic description and grouping was executed according to Mary Ownby's technique (see Appendix C) and the direct interpretation of possible provenance and raw reconstructing ancient technology are provided in this section. Based on the matrix activity (fired clay type and inclusions) and ceramic technology, the 25 samples were divided into three distinct petrographic groups (Group A, B and Outliers). Because some variation was noticeable within Group A, it is divided into three sub-groups: A.1, A.2 and A.3. Group A is comprised of ceramic potsherds from F6, F3 and Al-Khidr in Failaka and samples from Barbar Temple II and III in Bahrain. The Group B collection comprised only samples from the Mesopotamian House at F6.

The Outlier group is comprised of samples from the Mesopotamian House, F6 the Palace and Al-Khidr in Failaka, and Barbar Temple II in Bahrain.

### **8.3.1 Petrographic Analysis of Group A**

Group A.1 can be characterized by iron-rich silty and micaceous clay, which was sand-tempered (Figure 8.4). Samples of this group belong to the reddish and yellowish typical Barbar potsherds from Trench E and the Palace Period 1 at F6 (nos. 13617, 15128) and one sample of the contemporary site on Bahrain, Barbar Temple II (no. 13664). Also, three samples from Al-Khidr (Period1-2) are included (nos. 13701, 14259, 14288) as well as Northeast Temple ARU that is contemporary to Failaka Period 2. The Group A.1 includes only two Barbar ware types that are B-ware (nos. 13664, 13676), and C-ware (nos. 13617, 14259, 14288, 15128) which are all hand made. B-ware is as well-fired as A-ware and strongly tempered with sand. The grains of sand are comprised mainly of possibly quartz and strongly rounded as pointed by Højlund (1987:103). C-ware is relatively high-fired and the clay is medium-tempered with sand finer than A- and B-ware. The rounded quartz is verified in the petrographic thin section (Ownby, Appendix C:5).

The Group A.2 interestingly consists of two of the most important potsherds that come from the Palace Period 1 at F6 (Figure 8.5). These two sherds sometimes are clustered as outliers and/or close to the pXRF Group. Both are atypical of Barbar tradition and assumed to be imported sherds, in particular no. 13620. They are assigned as a subgroup of Group A because they share the iron-rich silty and micaceous clay in Group A.1 but lack sand temper (Ownby, Appendix C:5). However, the texture of both Group A.2 samples are different from Group A.1 as it is so oriented and has glassy fine grains. The edges of both sherds are glassy and darker than

the interior possibly due to a high firing of the outer surface. The glassy texture and edge could be a result of the higher temperature, above 850°C as for no. 13618 (see Appendix C:6). It was assumed that grog, an additive of old pottery fragments, was used in sample no. 13620. However, the inclusion in the sample was identified as limestone.

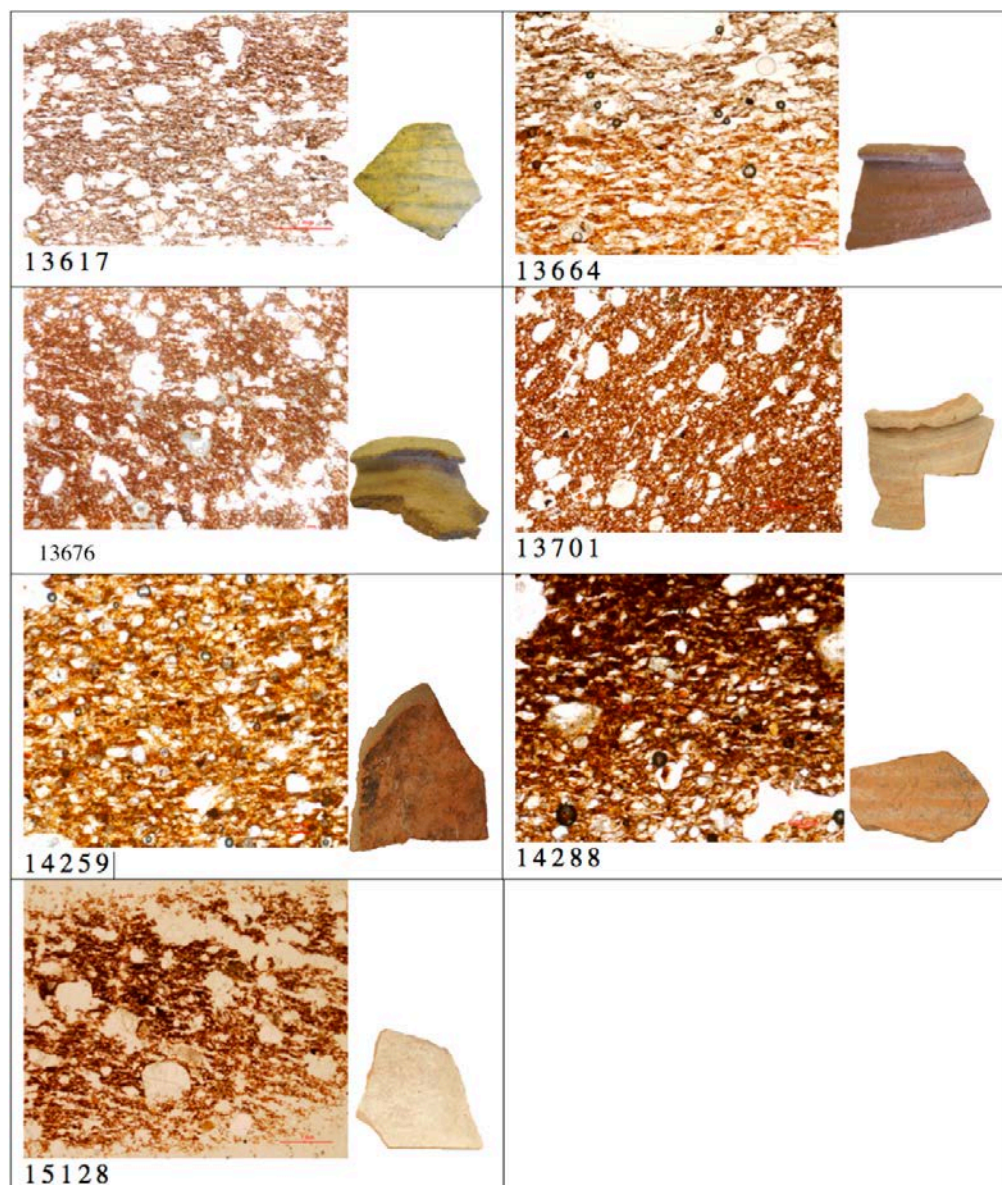


Figure 8.4 Thin section micrograph of the Group A.1. All samples in this group belong to Barbar tradition that is comprised of iron-rich silty and micaceous clay and sand temper. All images taken in plain polarized light.

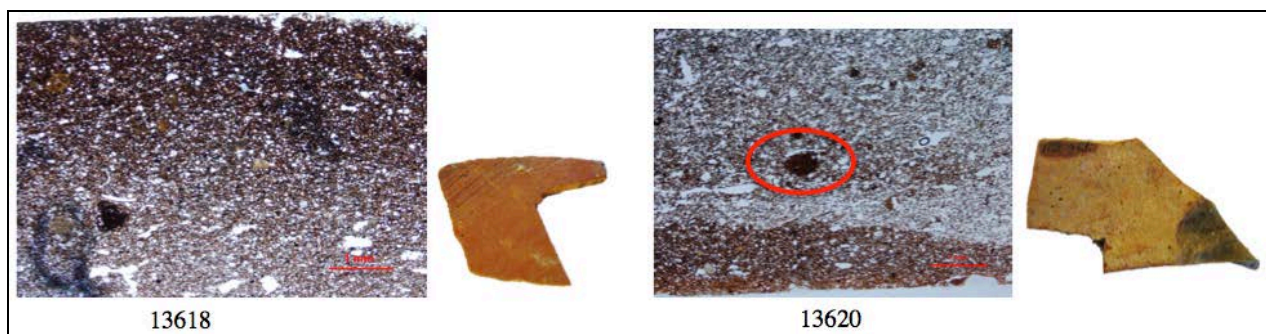


Figure 8.5 Thin section micrographs of Group A.2 samples. Limestone inclusion (red circle) in sample 13620 and darker edge in both sherds are noticed. All images taken in plain polarized light.

Group A.3 can be characterized by the same temper materials in Group A.1, sand temper, in addition to the different clays and iron-rich silty and micaceous clay of Group A.1 (Figure 8.6). Therefore, this group is the most problematic to ‘fingerprint’. Any ceramic sherds in this group may consist of a variation of clay types that might represent nonlocal clay or a subgroup of local clay different from the one used in Group A.1. The eight samples of Group A.3 came from the Palace F6, F3, and Al-Khidr in Failaka, and Barbar Temple II, NE Temple and Qala’at in Bahrain. They date to Period 1 and 2 on Failaka Island and Barbar II and III and one local sherd from Qala’at IIF, ca. 2000-1750 BC. This group is comprised of a variety of Barbar and Mesopotamian ware types: A-ware (no. 13622), B-ware (no. 13634), C-ware (e.g. nos. 13631, 13662) and E-ware (no. 14231).

Furthermore, in terms of technique, this group is comprised of wheel-made and handmade sherds. It includes the C-ware wheel-made (no. 13631) and B-ware handmade (no. 13634) from F3 Period 2 as they were made of the same sand temper. Sample 13634 was tempered similar to Group A.1 and made from iron-rich clay derived possibly from eroding shale while sample no. 13631 was made from a mixture of iron-rich and calcareous clay. This points to

variation in the use of clay and not just a single source to make handmade vs. wheel-made, at least for F3 pottery from Period 2. The difference between F3 Period 2 is also noticed in the firing temperature. The handmade sherd (no. 13634) was fired between 750-800°C while the wheel-made sherd (no. 13631) was fired above 800°C (Appendix C:6). Due to the sample size, a conclusion about the use of a specific clay source for a specific pottery type (e.g. wheel-made, storage jar) is difficult. However, a variation of clay types used to make local Barbar pottery is noticeable, during Failaka Period 1 and 2, ca. 1950-1800 BC.

The variation within a site is also noticeable between the Palace-like F6 Period 1 samples, with regard to the size of the sample. Both the F6 sample no. 13622 of Group A.3 and the Palace Period 1 sample no. 13617 of Group A.1 were made from micaceous clay. However sample no. 13622 also included an unusual calcareous inclusion and the clay was not silty (Ownby, Appendix C:6). The calcareous inclusion might be associated with the A-ware type of sample 13622 that is tempered strongly with sand and white lime particles. This white-yellowish lime was assumed to be crushed shell (Højlund 1987:103) that possibly came from Failaka shore where the sand is mixed with different grades of shell fragments (Højlund 1987:163). This assumption was enforced by the use of seashell in the ancient Arabian Gulf and Indus Valley. Seashell is composed mostly of calcium carbonate that has been used by craft specialists to make ornaments as in Harappa to trade them with Mesopotamia (Kenoyer 2008b:729) or make seal objects as uncovered in Al-Khidr in Kuwait and Saar in Bahrain (Benediková 2010:55). However, the thin section analysis indicated that the white-yellowish lime is limestone and not shell.



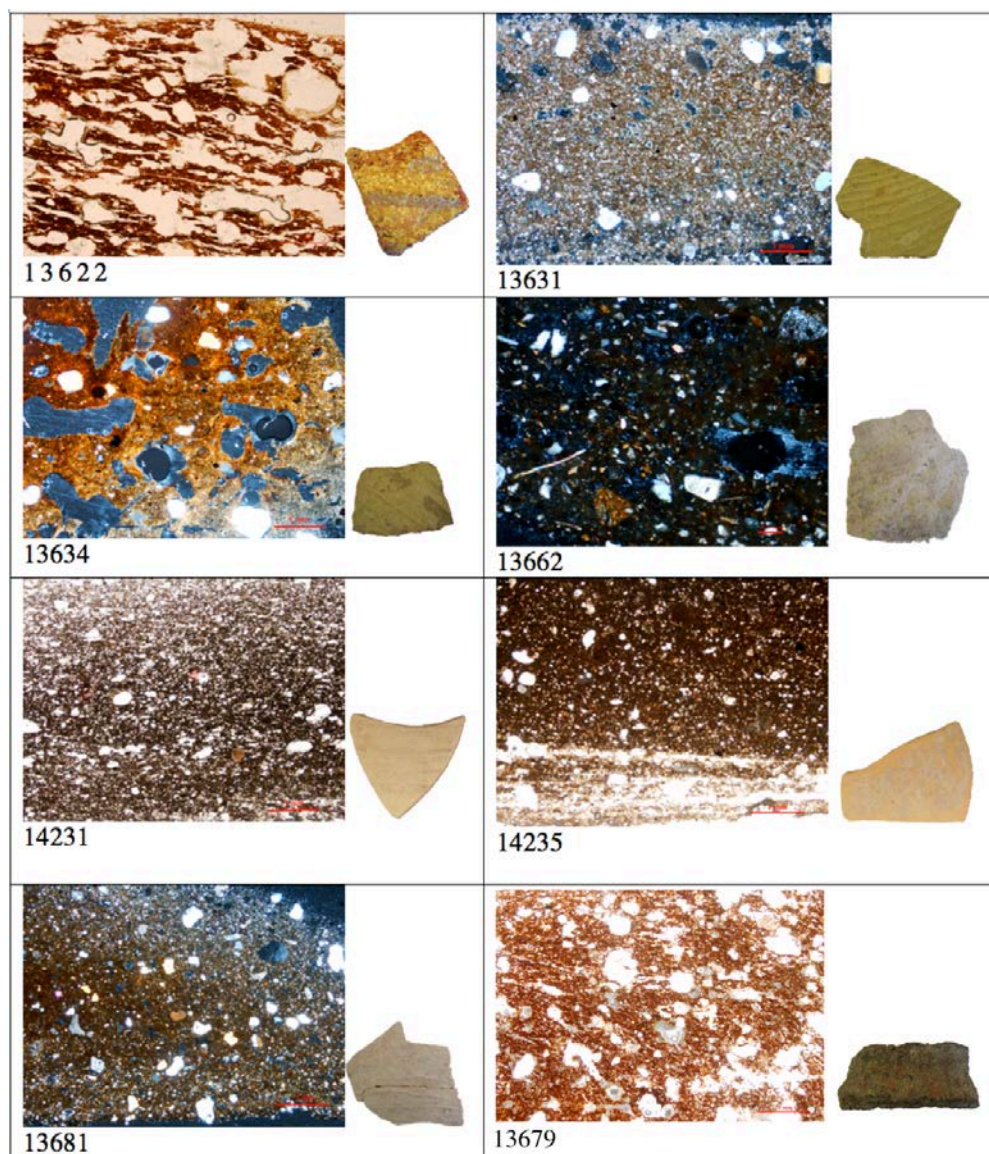


Figure 8.6 Thin section micrographs of Group A.3 samples showing a variation of clay types used for Barbar pottery. Images taken in plane polarized light (nos. 13622, 14231, 14235, 13679) and in crossed polars (nos. 13634, 13662, 13681).

Introducing calcareous components with salt particles would counteract the decomposition of calcite during firing and prevent the ‘lime popping’ or spalling phenomenon (Quinn 2013:158, 191). The presence of hollow on the early Dilmun pottery could be as a result of lime spalling which indicates the absence of salt during firing. This calcareous component appears also in sample 13681 (C-ware) from Qala’at IIF. This Barbar C-ware type could be

comprised of shells or a calcium carbonate component that has lime particles as does the A- and B-wares. It is important to note that there are five C-ware sherds in Group A.1 where the calcareous components are not shown in the thin section. Therefore, the calcareous component in the clay matrix could not be related to shell temper.

The Barbar II sample in Group A.3 (no. 13662) has a clay that was a mixture of iron-rich and calcareous components similar to Failaka F3 sample no. 13631 but the firing temperature is around 800°C (Ownby, Appendix C:6). Also, Al-Khidr sample no. 14235 has analogous clay as the latter but the firing temperature is below 800°C. All of these mixtures of clay type sherds are attributed to the Barbar C-ware type. Thus, it is likely that the mixture of iron-rich and calcareous clay was used to make some Barbar pottery from F3 and Al-Khidr in Failaka and Barbar Temple II in Bahrain from Period 1-2 and Barbar II, ca. 1950-1750 BC. The sample from NE Temple ARP (no. 13679) in Group A.3 is also slightly different from NE Temple in Group A.1 (no. 13676). The former was made from the iron-rich clay but had a few silty quartz and mica grains unlike Group A.1.

Finally, the sample from Al-Khidr (no. 14231) is also assigned in Group A.3 but it is the only sample that has mostly calcareous clay with a silty inclusion as in Group A.1. This sample is grouped within pXRF Group B but is assumed to be local by the painted and/or slipped lines on the outer surface (Benediková 2010 fig. 132f). The siltier clay and inclusions, which are more similar to those seen in Group A, have this sherd grouped with the local Barbar assemblage. The calcareous component in the clay may explain why it is chemically grouping with the Mesopotamian samples, which petrographically appear to be more calcareous (Mary Ownby, personal communication 2014). Stylistically speaking, all Group A.3 samples belong to the Barbar tradition ware types A, B, and C, are handmade and wheel-made (only for No. 13631),

and were from three sites on Failaka Island and three sites in Bahrain.

Significantly, the latter group demonstrates that there is a variation in the use of clay types within each chronological phase. For instance, the petrographic thin sections showed that the F6 Period 1 samples had been made of iron-rich silty and micaceous clay as opposed to the iron-rich, non-silty clay. Barbar Temple II samples, which are parallel to Failaka Period 1, were made of iron-rich silty and micaceous clay versus an admixture of iron-rich calcareous clay. Also, Al-Khidr sherds showed some variation of clay use, iron-rich versus calcareous clays.

In general, the petrographic analysis has provided information regarding the clay type utilized in the Barbar tradition pottery, iron-rich and calcareous clay. This matrix was not restricted to a specific Dilmun ware type, or chronological phase, or to a certain archaeological site. In terms of temper and paste preparation, the Barbar pottery certainly was tempered with sand that included quartz, plagioclase, and potassium (K) feldspar.

Specifically, these grains also vary with Barbar assemblages. Some sand grains have feldspar while others do not. The paste of this group is not uniform as the grain proportion varies from 10-30%, except two samples 5% (no. 13618, 13620). The size of grains also varies from 'very fine to coarse', 'very fine to very coarse', except samples no. 13618 and no. 13620, to a 'fine to medium'. The grain shape ranges from 'angular to well rounded' and 'subangular to well rounded'. The grain sorting, which is a determination of grain distribution in the ceramic, indicates that all Group A samples are considered 'fairly' sorted, except for two samples that were good- to well-sorted (nos. 13618, 13620). These latter two samples were assumed as nonlocal, soft and hard, red clay. They were clustered slightly with pXRF Group A, and in DFA as outliers. They appeared petrographically as a distinct subgroup of Group A with a lack of sand temper. This lack explains the exception of those two sherds as having the lowest inclusion



proportion (5%) in petrographic Group A. This exception extends to the size of grains, which were fine to medium; unlike other Barbar samples the very fine to coarse.

In terms of firing temperature, it is obvious that there is a variation of firing temperature among Group A that varies from 700°C, 750-800°C and above 800°C. This variation is attested even within each chronological phase and within samples of individual sites on Failaka Island and Bahrain. The firing temperature can be determined based on optical activity and detecting secondary minerals or mineral phases. The term ‘optical activity’ refers to the change of birefringence of the mineral in the clay matrix. The optical activity of the matrix is observed by rotating the sample in crossed polarized light at high power (Quinn 2013:190). A change or loss of birefringence of a specific mineral and rock inclusion can indicate then an equivalent firing temperature.

Another approach was utilized to estimate the firing temperature by detecting secondary minerals or new mineral phases that occur at certain temperatures using X-ray diffraction (XRD). A pilot study was carried out on two samples from Al-Khidr (nos. 13965 and 13969) using powder XRD at the University of South Florida’s Center for Geochemical Research. The aim of the study was to determine the mineralogical composition of the mineral phases, both primary and secondary. The results showed that both samples have major mineral constituents such as quartz plagioclase and alkali feldspars, muscovite, and biotite as well as new-formed or secondary minerals (Stremtan et al. 2014). The most important mineral phase is gehlenite, a calcium-rich sorosilicate, which formed during the reaction of clay minerals and calcite at temperature of 850°C (Stremtan et al. 2014). The presence of non-transformed or partially transformed inclusions (e.g.  $\text{CaCO}_3$ ) in both samples suggested a firing temperature lower than 800°C (Stremtan, personal communication 2011).

In terms of firing condition, the zonation of the clay matrix is observed in Group A samples. Some zonation has also been observed in other Barbar sherds that were not included in this analysis (Figure 8.7). It is a characteristic of thick, handmade red-ridged pottery jars. The red/brown margin and light colored interior, in addition to the absence of grey/black matter is indicative of organic-poor clay that was fired in an oxidizing atmosphere (Quinn 2013:199). This is the characteristic of A- and B-ware as in sample nos. 13664, 13694, 13699, and 13701. Moreover, the absence of a dark core indicates the porosity of the clay body and a sufficient firing period that allowed the penetration of oxygen. If there were a red or light margin and a dark gray or black core, this would indicate a short firing, as in sample no. 15128 from Trench E of F6 Period 1 on Failaka Island.

Also, the variations in the margin and core colors suggest a variety of firing time. Features as incomplete oxidization of iron and organic matter in ceramics are a characteristic of open firing in which it was difficult to control the temperature (Quinn 2013:203). Even though three open-air kilns were uncovered at F3 surrounded with a few Barbar tradition wares from Period 2 and 3A and 3B, there is no direct evidence of the activity of firing pottery or discarded kiln-made remnants, such as warped pots or fragments (Højlund 1987:171-73).

### **8.3.2 Petrographic Analysis of Group B**

Group B was comprised of four samples which all came from the Mesopotamian House structure at F6 on Failaka Island (Figure 8.8). The fine volcanic rock fragments, some likely basalt, characterized group B. Notably, no temper was added, but inclusions were naturally present in the clay. There were two clay types utilized in this group that are related to different ceramic types. First, the iron-rich and calcareous clay was utilized for the red, gray-on-red

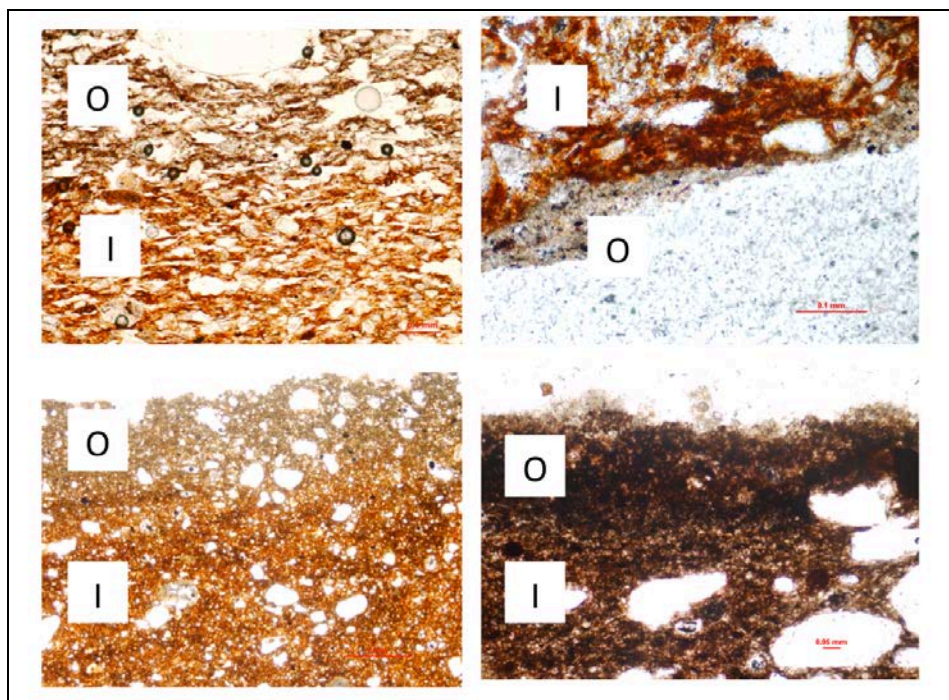


Figure 8.7 Thin section micrographs of zonation in Barbar red-ridge jars. The outer (o) margin is darker than the inner (I) of the core due to rapid firing and cooling. Top right (no. 13664) and left (no. 13701), and bottom right (no. 13699) and left (no. 13694).

Mesopotamian tradition, hand and wheel-made sherds (nos. 15154 and 15158). The second type, the calcareous clay, was utilized for the Mesopotamian tradition greenish and reddish hand and wheel-made sherds (nos. 15156 and 15166). Thus, there is no correlation between the clay type and sherd color. The color of sherd no. 15156 is very reddish orange, but has the calcareous clay that is associated with pale gray and whitish colors. This sherd has iron-rich components but it might have high iron-rich components that turned the clay to the red color. Also, there is a correlation between the clay type used and the technique employed. For instance, the calcareous clay was utilized in both red handmade and green wheel-made sherds. Interestingly, all these calcareous clay sherds were clustered together as a distinct pXRF Group B.

The paste of this group was respectively uniform as the grain proportion is 10%, except one sample was 20%. The size of grains was less varied than Group A; grain size ranges ‘very

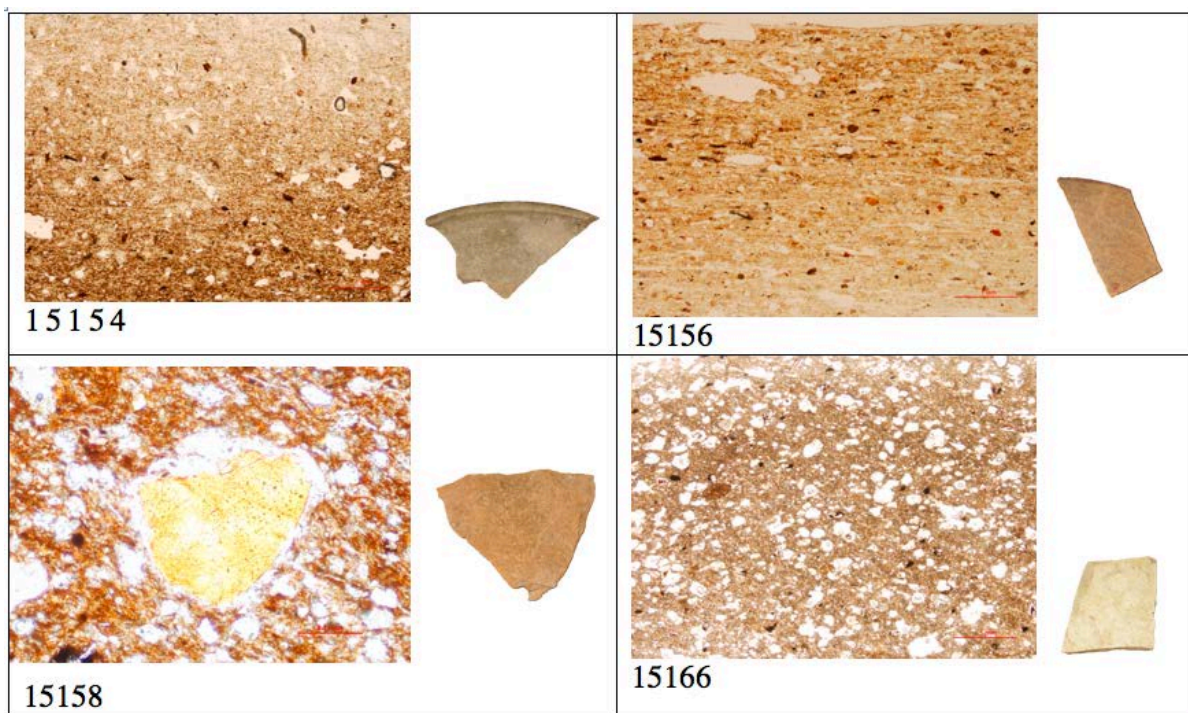


Figure 8.8 Thin section micrographs of Group B samples that have a fine grain texture and calcareous clay. All images taken in plane polarized light.

fine-to-fine' (nos. 15154 and 15166) and 'very fine-to-medium' (nos. 15156 and 15158). The grain shape was uniform as all shared the angular to subangular shape range. Three samples were sorted as 'good', except one, which is 'well' sorted (no. 15154). The firing atmosphere of Group B was observed to be uniform in texture and with a light core which indicates sufficient oxygen penetrated the body and removed the carbon. The uniformity was also observed in the firing temperature in which all were fired at about 800°C. Interestingly, it was obvious that the heavily calcareous components of Group A.3 sample 14231 made it group chemically with Group B.

### 8.3.3 Petrographic Thin Sectioning Outliers

The final group is the Outliers that were comprised of four samples from F6 the Palace, the Mesopotamian House and Al-Khidr in Kuwait as well as one sample from Barbar Temple II

(Figure 8.9). Three samples were grouped to some of the pXRF groups, while the Al-Khidr sample remained an outlier in both the pXRF and petrographic analyses. The main characteristic of these outliers is that they all lack temper. Sample no. 13613 which came from F6 the Palace has iron-rich clay and silty and micaceous inclusions. The lack of temper along with the presence of iron-rich and micaceous clay apparently put the sample as an outlier. The similar clay of nos. 13613, 13618 and 13620 is why they chemically grouped together. Basalt fragments made sample no. 13613 unique. According to the pXRF results, all three clustered closely together. All three sherds were assumed to be non-local that came from the Palace Period 1 at F6. Their firing temperature varied (750°C, 800°C, and 850°C). They share a feature of 'well' sorted.

Sample no. 13661 that came from Barbar Temple II was assumed to be a Barbar green sherd that belonged to the C-ware type. It was grouped with the pXRF Mesopotamian Group B due to the calcareous clay that lacked mica (Ownby, Appendix C:7). There is one Barbar (no. 14231) calcareous and silty/micaceous clay sample, which was clustered in Group A.3, but not the purely calcareous and green clay of no.13661. They were both wheel-made Barbar green sherds but the outlier seemed to be made from another clay source.

Interestingly, sample no. 13661 has elongated pores that has been associated with wheel-made technology (Ownby, Appendix C:7: Stremtan, personal communication 2013). Some variations were noted in both samples in terms of firing temperature (800°C vs. 850°C), grain sorting, grain proportion, and grain shape and size. They were both fired above It might be similar to the case of Al-Khidr sample, no. 14231 that is grouping chemically with pXRF Group B. Again, Group B has been defined by the calcareous clay that is comprised of a grayish green Mesopotamian tradition. The presence of calcareous components could affect the chemical results and compositional group.



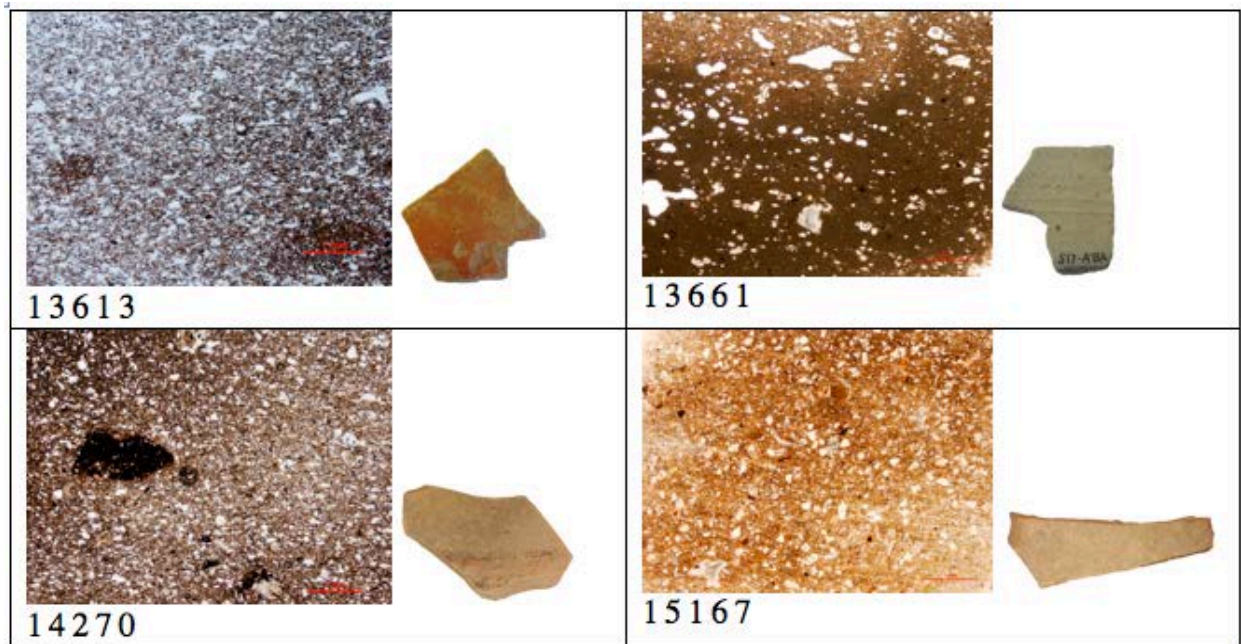


Figure 8.9 Thin section micrographs of Outlier samples from Failaka and Bahrain sites. All images taken in plane polarized light.

Sample no.14270 came from Al-Khidr and was assumed to be of the Eastern Tradition sherd (i.e. regions from Iran to India). Similar to sample no. 13613, it appears as an outlier from both pXRF and petrographic thin section analyses. The grayish, red clay matrix could be the result of the use of iron-rich and silty/micaceous with a calcareous component, lacking silty inclusions unlike Group A. The grayish, brown color of the clay matrix is also noticeable in other samples that were made of iron-rich and calcareous clays. The abundance of large clay pellets was noted by the unusual inclusions that were clay-rich with minor silty inclusions (Ownby, Appendix C:7).

Finally, sample no. 15167 which came from the Mesopotamian House, has similar calcareous clay as Group B, particularly sample no. 15156, but with a few similar volcanic fragments and prominent fragments that resemble schist (Ownby, Appendix C:7). Both samples had a tan color in the clay matrix and the inclusions were sorted as 'good'. The firing

temperature of no. 15167 seemed to be fired slightly lower than other Group B samples, which varies from 750-800°C and 800-850°C. This sample shared the firing atmosphere of Group B, as it has a darker core and a lighter margin. Although this sample sorted chemically with the pXRF Group B of the Mesopotamian tradition and seemed relatively related to those in petrographic Group B, it still showed some different raw materials from Group B (Ownby, personal communication 2014).

#### **8.4 The Potential Provenance of Bronze Age Pottery**

There were notable features in the Bronze Age ceramic groups in terms of fabrics and paste type and rock clasts as well. A characterization study would then be possible after identifying the minerals and classifying the rocks under the microscope. The aim at this level would be to create and define groups and subgroups based on the description and classification of mineral inclusions, paste, and associated features, such as firing process. After the characterization study, a comparison between the petrographic data and possible geographic locales would be done to locate ceramic production sites.

A provenance study is out of the scope of this inquiry for two main reasons, even though there is an attempt to ‘fingerprint’ production centers. The question central to the research was to determine the scale of Barbar ceramic production and the level of standardization in the early second millennium BC. Thus, characterizing ceramic mineralogical compositions would be sufficient to compare pottery from a defined production center. Second, a provenance study assumes the existence of a database that contains the geological features of the said region as well as its geochemical profile. The very nature of trade, exchange and interregional interaction during the Bronze Age would require a wide database of several regions. Therefore, one of the

main research goals was to characterize the paste and temper of Bronze Age sherds to compensate for a missing database. Even with the data available, the heterogeneity of ceramic composition due to the coarse materials added to the clay (Rice 2005:424) or to the mixing of various local clay types as in the Dilmun pottery would raise a problem in the determination of provenance; furthermore, for a ceramic tradition to a specific region in which multiple workshops and production centers (Failaka vs. Bahrain) were possible is difficult.

Interestingly, the only petrographic study on Barbar wares was carried out on pottery found at the Mesopotamian Larsa and Shimal sites on the Omani peninsula, from later third to early second millennium BC (Méry et al. 1998). The results of this analysis was compared and contrasted with the Failaka and Bahrain thin sections. The Barbar pottery from Kuwait and Bahrain fall into three clay type groups: iron-rich silty and micaceous, iron-rich and calcareous, and calcareous clays. Some variations were noticeable within the iron-rich clay type; thus, sub-groups into silty, non-silty, and micaceous. They were all tempered with sand, except Group A.2, which lacked temper (assumed as non-local).

Three Dilmun potsherds from Mesopotamian Larsa and Shimal in UAE were subjected to thin section analysis. A number of six Barbar potsherds were also obtained from Bahrain (Qala'at, Barbar I-II, and Saar tumuli) as a reference group. The results showed the Dilmun group as characterized by a coarse temper, fragments of quartz, and feldspathic sand that was composed of quartz mixed with plagioclase, orthoclase, perthites, epidote and amphiboles (Méry et al. 1998:137). However, this group showed some variation in terms of the amount of temper fraction that varied from 15-20%, 20-25%, and 25-30%. Only one sherd that came from Bahrain tumuli, as a funerary jar, showed a very different temper amount of 5% and very small grains of quartz (Méry et al. 1998:138). The two Barbar potsherds from Shimal in UAE were also related



to Dilmun of Qala'at and Barbar Temple but the Larsa jar was not related directly to Dilmun reference potsherds - less temper than 5% and no micritic carbonate. In the Méry et al. (1988) study, the Dilmun sherds seemed similar to those in Group A from Failaka and Bahrain, in terms of temper proportion (from 10 to 30%) and they had similar inclusions (e.g., quartz, plagioclase, epidote, amphiboles, micas and micritic carbonates).

Among Group A, lesser temper, the presence of volcanic rock fragments, and possible granite and lack of temper but similar clay of Group A is what partitioned sample no. 13620 and placed it in subgroup Group A.2. It was assumed that this sherd was non-local and could be related to the Harappan tradition (Højlund, personal communication 2010). However, it is possible that the samples that lack exclusively weathered schist and fine quartz could rule out the Indus Valley as the origin (David Hill, personal communication 2014). Amphiboles, biotite, and schist were a very common component in Harappa pottery (Patel: n.d.).

Also, the local appearance of this sample might be explicable, if there are volcanic and sedimentary rocks. The closest pure volcanic outcrop is the Cretaceous ophiolite ridge in the Omani peninsula. However, this ridge does not extend into the Bahrain formation; it is about 600 km across through the Omani peninsula to the Bronze Age settlement of Shimal in UAE (Méry 1991b:249). Regarding the other Group A.2 sample, it seems that sample no. 13618 could be related to local Barbar tradition. No distinct features have been observed except the absence of temper and 5% natural inclusion, in relative to the temper of Group A.1 (10-20%). As aforementioned, there are two Barbar potsherds that have been found in Mesopotamian Larsa and Buri tumuli in Bahrain (Méry 1998), which are comprised of only 5% temper materials. Therefore, the F6 sample could be similar to them as presumably noticed as an uncommon flat

local sherd (Højlund, personal communication 2010). This raised the question regarding the function of this type of pottery that was locally made, but wheel-made and less tempered.

In relation to Omani Peninsula geology, the basalt embedded in iron-rich clay could also explain the production center for sample no. 13613. Basalt is one of the two major zones in the base of the Semail ophiolite in the Omani Peninsula (Searle and Malpas 1980). The circulation of hard, red-colored pottery from this area to Dilmun was observed during the Umm an-Nar period, in the late third millennium BC. The red fine ware from Hili 8 in UAE has been discovered during this period at Hamad Town in Bahrain. The compositional feature of these sherds was the granite-gneissic rocks (Méry 1988:2). Based on the ceramic texture and non-plastic fraction, it is possible that sample no. 13613 could be from the Omani Peninsula. If the latter is true, then the challenge would be to ‘fingerprint’ these two samples (nos. 13613, 13620) to a particular location within the Omani peninsula.

Dilmun ceramics all have a carbonaceous feature that reflects the principal outcropping of rocks in Bahrain: the Eocene formation (Rus and Dammam formation) that is made up of carbonate and dolomite beds (Doonrkamp et al. 1980; Willis 1967:1). Within the Eocene and Miocene, the two principal and newest rocks in Bahrain, the dominant rocks are limestone, chalk, dolomitic limestone, shales and marls (Willis 1967:1). The earliest formation in Bahrain, Lower Eocene or the Rus formation consists of chalk and chert bearing dolomite – that occurs only in the central of Bahrain. Following the Rus formation, the Dammam formation is correlated with the eastern Saudi Arabia. The rock consists of brown crystal limestone, orange marl, and white limestone. The younger rock formation is Miocene that comprises a sequence of clay, shale, marl, limestone and calcareous limestone (Willis 1967:4). The Recent formation (Quaternary) is comprised of silt, gravel, sand and Sabkha deposits, and calcareous or

gypsiferous duricrusts, forming a sedimentary structure upon the interior platform of the Arabian Peninsula (Larsen 1983:120). A distinct green silt and clay can be found in “Daya” which occurs in two parts in Bahrain: in the north of Bahrain 15-20 km south of Barbar and Qala’at sites, and in south Bahrain 35 km away from Dilmun. Dayas are depressions in the limestone, chalk or gypsum bedrock surfaces that appear a few meters deep (Doonrkamp et al. 1980:119). The green clay, of a high dolomite and calcite content, is a feature that can be found under brownish silt in a daya deposit. The green clay and marl are mineralogically similar to the Dil’Rafah carbonate formation, mainly quartz, feldspar and attapulgite, which is also characteristically a green bed (Doonrkamp et al. 1980:19-22). The latter supports the presence of green local Barbar pottery (NE Temple nos. 13670, 13671, 13673, 13675, Qala’at IIIA 13691) that was compositionally clustered with the local red Barbar collection in pXRF Group A. If this can be confirmed mineralogically under a microscope, it means that the green clay was utilized for Barbar ceramic production beginning with the Northeast Temple, parallel to Failaka Period 2 ca. 1850 BC. The non-silt and lack of mica and sedimentary inclusions in green Barbar II sample no. 13661 would confirm it as a non-local ware. This sample was presumed to be a Barbar II green sherd but clustered with the Mesopotamian House collection Group B and as an outlier in the petrographic compositional group. This was the only sherd that was presumed Barbar among 75 sherds. It was also the only sherd that was fired above 850°C and unparalleled to any sherds of the first third of the second millennium BC. It is possible that this sherd, green, wheel-made, could have come to Bahrain during the Isin-Larsa period, paralleled to Barbar Temple II ca. 1950-1850 BC (Ashkanani and Tykot 2013:260). If it happened, it seems that this sherd was made out of different clay and inclusions, unlike the Mesopotamian Group B.

In Kuwait, rocks date to around an early Miocene to Holocene epoch and are exposed on the surface. They consist of fine silt and clay with a high salt content, lithic and shelly limestone, and calcium carbonate sand for beach deposits (Milton 1967:5). In the north of Kuwait, the Holocene deposits consist of plastic clay and silt with high saline that was deposited by the Tigris-Euphrates River system (Milton 1967:5). The Miocene to Pleistocene is characterized by the Dibdibba formation that is composed of sand, and gravel with minor clay and a gypsiferous sand clay bed. The gravel was recognized as two different groups. The first group was composed of quartz and metamorphic rocks with lesser igneous rocks and others. The second group was composed of various mafic and silicic volcanic rocks, though it was derived from the flow of Syria and northern Arabia (Milton 1967:5). This Dibdibba formation covers exactly the upper portion of the Kuwaiti mainland (Jahra city to Iraq boarder north, and to Wadi al-Batin west) while the lower portion (Kuwait city to the Saudi Arabian boarder) is in more well-sorted sands and silty sandstone. This is the Far formation that dominates the lower portion of Kuwait which is dominated by the red and yellow sand, red and green clay, gypsum layer, and sandstone silty clay (Milton 1967:5-6, UN-ESCWA and BGR 2013:599).

Having calcium carbonate in both Kuwait and Bahrain makes it difficult to differentiate between Barbar calcareous-clay ceramics. While northern Kuwait is distinctive in the presence of volcanic and igneous rocks, the lower portion of the mainland and Bahrain are dominated by limestone, calcium carbonate, dolomite, silty clay, shale and marl. It has been noticed that the Bahra formation in Kuwait shares the sandstone with the lower producing formation of Bahrain (Milton 1967:2; Alsharhan and Nairn 2003:217). The green clay has also been identified in Bahra in south Kuwait in the Ghar formation which might have a similar mineralogical composition to 'Dayas' in Bahrain. At this level, it would be unlikely to be possible to

differentiate between multiple production centers within the Dilmun territory, at least between Failaka Island and Bahrain. This uniform structure respectively extends particularly in the Dibdibba formation to southern Iraq, in particular to the city of Basra (600km/380 mile north Kuwait) and the far northeast of Saudi Arabia, particularly Hafr Al-Batin (UN-ESCWA 2013:593).

Al-Qatif in KSA (110 km/70 mile NE Bahrain, 280km/450 mile south Kuwait) also has a calcareous nature of clay and sand like Bahrain and Kuwait. The eastern part of the Arabian Peninsula, including Al-Qatif, is known as a sedimentary soil shelf that is comprised of calcareous materials such as dolomitic limestone, marl and chert similar to the Bahrain geological structure (Azam 2006:87:88). However, some inclusions in Barbar potsherds could be good indicators for future studies. Barbar ceramic clay embedded with volcanic and metamorphic rock fragments could be a good start to map land use in the Bronze Age. It has been noted that some Barbar potsherds include volcanic rock fragments, such as Barbar nos. 13676 and 13679, and: Alkhidr nos. 13701, 14235, and 14259. In the future, a petrographic analysis on the volcanic and igneous components from the northern portion of Kuwait is necessary. It is a challenge to think how the ancient potter might have utilized volcanic components from a north Kuwait city with high salt content in the clay and sand, which may preclude the clay as pottery making materials (Ownby, personal communication 2014).

The outlier sample no. 14270, which was assumed to be of the Eastern tradition pottery (southern Iran to Indus), also was comprised of volcanic rock fragment like no. 13613 but also included micritic limestone and quartzite. The Eastern tradition is a term used to characterize pottery that came from southeastern Iran (Makran plain) to southern Harappa cities on the Arabian Sea coast (i.e. Lothal, Desalpur, and Albandino). Fortunately, one sherd similar to this

one was found in Bahrain without a definite provenance but resembled to the Indus Jhukar pottery from Chanhu Daro, Amir and probably Mohenjo Daro (Højlund 1994a:121-22).

The Makran in general is similar to the Omani peninsula that has mud volcanoes, sandstone, siltstone, shale, and some limestone; the mud volcanoes developed on the coast of the Oman Sea and in the province of Sistan and Baluchistan (Negaresh 2008:1-4). However, the Omani ophiolite formation does not appear in Makran, just one hundred kilometers to the northwest (McCall 2002). Thus, basalt could not be observed in the Makran bed. Gray painted pottery is characteristic of Makran in Pakistan as an important production of this region. It is a gray ware of incised pottery or of vessels with applied elements that have been found in the Omani peninsula in contexts of 2700-2600 BC and 2100-2000 BC (Méry et al. 2012). This gray painted or incised ware does not appear to be parallel to the outlier sample.

Further down, southeast of Makran, is where the Harappan city of Lothal is located in Gujarat province. The mainland of Gujarat is comprised of an alluvial plain that stretches to merge in the Rann of Kutch and the desert of Rajasthan (Kulkarni 1985). The Gujarat peninsula is characteristic in a number of hills that were formed and bear different rock types due to magmatic differentiation (Kulkarni 1985:4). In Ahmedabad district, where Lothal is located, a sedimentary deposit is the main feature and associated with dolomite, limestone, quartzite, pyllites and schists (Kulkarni 1985). This Jhukar pottery type was found at Harappa cities in Chanhu Daro and Amri and Mohenjo Daro (Dale and Kenoyer 1986:57). It is described as a painted design on red slip with additional use of red and brown color as a new decorative style for the Harappa culture. In the early second millennium, the Jhukar pottery appeared in the Gujarat sites in the context that followed the Mature Harappa (Cemetery H) with large

dominated painted black-red ware (Mughal 1992:215-16). The enclosed net pattern, common on Jhukar pottery, was found in Lothal, Chanhu Daro and Mohenjo Dar (Carter 2005:168).

The Lothal materials were found in Dilmun during the early second millennium BC supporting the continuity of contact with the Late Harappa people. Late Harappa materials were observed at the Dilmun sites of Saar and Qala'at in Bahrain from periods IIb and IIc, ca. 1950-1750 BC (Carter 2005; Højlund 1994a). There was a high concentration of Late Harappa materials from Lothal along with related Jhukar pottery in Bahrain and copper tools at Tell Abraq as well as in southern Baluchistan. It seems that the Lothal port was a gateway for Chanhu Daro and inland cities to trade and exchange with Dilmun merchants during the first third of the second millennium BC, Barbar II-III/Failaka Period 1-2. Many materials associated with the Indus Valley from the same period were found in Ur and Bahrain and include: leather goods, wooden artifacts, ivory garments, and copper (Carter 2005:196; Cleuziou 1986). With the established Dilmun point on Failaka and Dilmun dominance over the Arabian Gulf in the early second millennium BC, it would suggest that Dilmun and Lothal were active partners in long-distance trade. This contact is attested by the important discovery of a Persian Gulf seal at Lothal, an Indus weight in Bahrain (Dani 1986), and a stamp seal with Indus script found on Failaka (Kjaerum 1986:271). The far-reaching commercial connection between Dilmun and Lothal could be further attested with this sherd from Al-Khidr, which seems to have served as a port of Failaka. It would be unsafe to build a conclusion based on one sherd, but it represents a promising avenue that shows some relation with foreign traders and trading communities.

## 8.5 Conclusion

These research results have demonstrated that pXRF can contribute valuable data to construct a database for chemical components of ceramics recovered from Failaka Island and Bahrain. Technically, this initial analysis shows the success of pXRF for examining the homogeneity of an artifact, identifying unknown samples, and testing the previously assumed origins for some ceramics. The pXRF device is a reliable tool to create compositional groups for production centers and to recognize ceramic centers that stylistic and descriptive methods can confuse. More data needs to be collected to identify the full range of clay variation for each production center.

Statistically, the principal component and cluster analyses successfully differentiated the samples based upon their elemental compositions and were confirmed by discriminant function analysis. The PCA shows a similar chemical compositional profile for Dilmun ceramics from Kuwait and Bahrain, suggesting a uniform chemical composition of ceramic production during the early second millennium BC. Along with PCA, discriminant analysis shows that the majority of Dilmun sherds from Failaka Island have the same compositional pattern as those from Dilmun sites in Bahrain, thus indicating they were made of the same raw material. Whatever the treatment of the outer surface or the color for the Dilmun vessels, the choice of using locally available raw materials is noticeable.

In terms of the pXRF performance, in comparison to the petrographic analysis, the pXRF ceramic group is congruous with the petrographic group for all Dilmun, Mesopotamian and outlier groups (Table 8.1). It shows that the Dilmun ceramic pottery is clustered in one pXRF group similar to the main group of petrographic analysis. The green and red Mesopotamian sherds found in pXRF group B are also clustered together in their petrographic thin sections. The



two outliers from the pXRF group also appeared as outliers in the thin section analysis. There are only three samples that are shown chemically as belonging to the Mesopotamian collection but grouped as outliers and one as Dilmun based on thin section analysis. The reason for the unmatched result is due to the presence of calcareous clay in local Dilmun pottery similar to the Mesopotamian collection. One Mesopotamian sherd is assigned as an outlier petrographically due to the different clay source used within the Mesopotamian territory and metamorphic inclusions as well as volcanic.

However, the pXRF instrument is unable to identify any subgroups within local Barbar pottery. These subgroups are related to the two clay types found in Barbar tradition, iron-rich micaceous and calcareous clays. Using the current setting, on the pXRF device, with a filter (12 mm Al, 1 mm Ti, 6 mm Cu) and settings of 40 kV and 11  $\mu$ A to maximize trace element analysis of Ba, Nb, Rb, Y, Sr, Zr and Th, the device is clearly able to cluster all local traditional pottery into one distinct group.

The following petrographic groups combined iron-rich and micaceous silty clay (Group A.1), iron-rich and micaceous not silty and admixture of iron-rich and calcareous clays (Group A.3), and iron-rich and micaceous clay with no temper (Group A.2). However, pXRF is significantly able to differentiate between Barbar tradition iron-rich silty and micaceous clay and Mesopotamian tradition iron-rich and calcareous clays. Also, it was able to create another compositionally distinct group of outliers.

Similar to variation within Dilmun pottery, a chemical subgroup of Dilmun pottery was also observed within Barbar tradition pottery found at the Saar site (Bahrain) and at the Tell Abraq site (Oman). A proton-induced x-ray and gamma-ray emission (PIXE/PIGME) analysis was carried out on 665 Barbar potsherds at Tell Abraq to obtain major and minor elements. The

Table 8.1 Summary of pXRF groups in relation to petrographic groups.

No.	Site	Tradition	Type	pXRF	Thin section	
13617	F6 Palace	Dilmun	C	A	A.1	Iron-rich silty and micaceous plus temper
13664	Barbar II	Dilmun	B	A	A.1	Iron-rich silty and micaceous plus temper
13676	Barbar ARP	Dilmun	B	A	A.1	Iron-rich silty and micaceous plus temper
13701	Al-Khidr	Dilmun	C	A	A.1	Iron-rich silty and micaceous plus temper
14259	Al-Khidr	Dilmun	C	A	A.1	Iron-rich silty and micaceous plus temper
14288	Al-Khidr	Dilmun	C	A	A.1	Iron-rich silty and micaceous plus temper
15128	Trench E	Dilmun	C	A	A.1	Iron-rich silty and micaceous plus temper
13618	F6 Palace	Indus?	-	A?	A.2	Iron-rich and micaceous no temper
13620	F6 Palace	Indus?	-	A?	A.2	Iron-rich and micaceous no temper
13622	F6 Palace	Dilmun	A	A	A.3	Iron-rich and micaceous, not silty
13631	F3 - 2	Dilmun	C	A	A.3	Calcareous and silty
13634	F3 - 2	Dilmun	B	A	A.3	Iron-rich and not silty
13662	Barbar II	Dilmun	C	A	A.3	Iron-rich and calcareous
13679	Barbar IIIARP	Dilmun	A	A	A.3	Iron-rich
13681	Qala'at IIF	Dilmun	C	A	A.3	Iron-rich and calcareous, plus micaceous and silty
14231	Al-Khidr	Dilmun green	C	B	A.3	Calcareous silty and micaceous
14235	Al-Khidr	Dilmun	C	A	A.3	Calcareous and silty
15154	Meso. House	Meso.	Wheel	B	B	Iron-rich and calcareous, plus micaceous
15156	Meso. House	Meso.	Wheel	B	B	Iron-rich and calcareous
15158	Meso. House	Meso.	Hand	B	B	Iron-rich
15166	Meso. House	Meso.	Hand	B	B	Calcareous and silty
13613	F6 Palace	Indus?	-	O	O	Iron-rich and micaceous, not silty
13661	Barbar II	Barbar	-	B	O	Calcareous and not silty
14270	Al-Khidr	Eastern	-	O	O	Iron-rich and calcareous, plus micaceous and silty
15167	Meso. House	Meso.	Hand	B	O	Iron-rich and calcareous, plus micaceous
Meso. = Mesopotamian						

results showed that the classic Barbar pottery fell chemically into two groups (Grave et al. 1996:179). These results were compared by means of PCA to the XRF results for Saar Barbar pottery that was carried out by Marlies Heinz's 1994 study (in Gravel et al. 1996). The results also showed that there were two major groups and strongly confirmed the match between XRF and PIXE/PIGME (Grave et al 1996:183). The absence of major elements, such as iron (Fe), magnesium (Mg), calcium (Ca), titanium (Ti), potassium (K), and silicon (Si) in our pXRF data due to the analytical settings can certainly preclude creating more subgroups within Barbar pottery.

In order to obtain a wide range of elements, alternative settings are highly recommended in pXRF studies to obtain additional major and trace elements in these samples. A setting of 40kV/1.5 $\mu$ A with a vacuum, but with no filter has been used recently to obtain Si, Al, K, Ca, and Ti to characterize ceramic artifacts from Northwestern Florida (Tykot et al. 2013:240). In another study, a different setting (12kV/15 $\mu$ A) was applied in the pXRF device to obtain Al, K, Ti, and Ca elements for American Southwest Mimbres pottery (Speakman et al. 2011). According to XRF and PIXE/PIGME results, Si has a major role in the partitioning of Barbar pottery from Tell Abraq and Saar (Grave et al. 1996:183). Also, it is possible that the absence of iron-related elements (e.g., Al, Si, Mg) and micaceous and calcareous-related elements (e.g., Mg, Fe, Ca,) could contribute to less discrimination among Barbar potsherds, unlike the variation within petrographic results (e.g. iron-rich Group A.1 vs. calcareous components Group A.3).

Using different settings in the future will provide more information about the performance of pXRF in grouping Barbar potsherds and a possible correlation with the petrographic thin section results and other analytical techniques. Also, utilizing different calibration software and creating a certain calibration for the Arabian Gulf pottery is

recommended. It would help to assess the data and compare with regular XRF as real values instead of 'internally consistent'. Despite the heterogeneous surface analysis, data obtained from pXRF showed its significance lies in the partitioning of Bronze Age ceramic artifacts. The three major pXRF groups show significant agreement between the macroscopic description and the elemental composition groups. For example, Group A correlates to all Barbar tradition, Group B relates to grayish green Mesopotamian tradition, and pXRF Group C reflects the 'caramel ware' of the Kassite period. Interestingly, the latter group is clearly partitioned from Mesopotamian House by the very high concentration of Sr, Ba, and Rb. The Sr element is related to plagioclase feldspar, pyroxene and carbonate minerals, which is higher than any group. The Ba element is probably high due to rich granite, granodiorites and other felsic igneous rocks. The Rb, which is higher than Group B, could be related to the micas content.

The compositional elements Rb, Zr and Sr contribute more in the Barbar group than the Mesopotamian collections. Rb is associated with biotite, muscovite, granite and hornblende. This is parallel to the rich micaceous clay and major inclusion of biotite and muscovite in Group A. Sr also appears as plagioclase feldspar and in the carbonate minerals in clay. Zr is considered a temper element not clay material. Based on the pilot study, it was found in eight samples from Al-Khidr, one from Qala'at III, and one from F6 the Palace that are not included in the Appendix. They appear in different sizes as rounded sit on quartz and/or feldspar. The compositional elements Nb, Y and Th are relatively less variable between the three groups as well as with Harappan and Iranian groups.

Among the 25 samples analyzed for petrographic analysis, four samples were identified as outliers. Two of them were already in the pXRF outlier group. The other two were presumed related to their production centers, but the lack of some inclusion. In addition to the latter, only

three presumed Mesopotamian samples (straw-temper) from Al-Khidr were not matched compositionally with Group B. The overlap of some samples from Failaka and Bahrain with the Mesopotamian group support the strategy utilized to create a reference group for pXRF and petrographic analysis.

According to petrographic thin section analysis, the clay utilized to produce Barbar pottery seems to have been obtained from different clay sources that are related to the same main compositional source. The multiple clay types (i.e., iron-rich silty and micaceous, micaceous not silty, calcareous, iron and calcareous) point to the heterogeneous nature of a certain local clay source. Even though the sample size is small for the Barbar pottery ( $n = 16$ ), there is a pattern of using at least four clay sources that might be located in the vicinity of Dilmun sites in Bahrain and perhaps Failaka. There is no correlation between specific clay and a particular Barbar ware or chronological phase. It was observed that a variety of clay types were utilized within a certain period, either on Failaka or Bahrain. For instance, the iron-rich, micaceous samples' group represents Period 1 and 2 on Failaka and Barbar II and III, a range of 150 years. Moreover, this group also comprises both B- and C-ware types, making no difference between heavily and medium sand-tempered sherds. The variety of sherd colors in this group (i.e., red, yellowish brownish sherds vs. pink, red, and gray slip), along with possibly using a single clay source, could suggest using different firing techniques, within a certain phase, which affected the colors; the Group A firing varies from 700°C, 750-800°C and above 800°C. A sherd from the later phase Barbar NE Temple ARP is the only sherd that was fired above 800°C even though it is unlike the other sherd from the same phase and site. This could imply to an improvement in the firing in the later phase but it is unsafe to build a conclusion based on one sample. Based on the zonation in the thin section slides, the ceramic artifacts were fired in different atmospheres,

reducing and oxidizing firing technology. This difference might be related to different types of kilns and/or the lack of firing control. Therefore, this variation would support a variation on firing temperature noticed. Since there is no kiln reported in Dilmun sites, the vessel seemed fired in an open kiln or in a pit.

In terms of the temper utilized in Barbar pottery, there is a variation amongst the Barbar pottery collection. The majority had sand temper and others calcareous components; some sherds show less quantity of some sand temper inclusions. Grog temper has not appeared in any Barbar group. The grains also vary with Barbar assemblages. The paste of this group is not uniform as the grain proportion varies from 10-30%, except one sample 5%. The size of grains also varies from very fine to coarse, very fine to very coarse, and fine to medium. The grain shape ranges from angular to well-rounded and subangular to well-rounded.

Both pXRF and petrographic analysis were able to discriminate between typological categories from amongst samples from Kuwait and Bahrain. pXRF can contribute valuable data to construct a database for chemical components of ceramic pottery wares recovered from Dilmun sites in Failaka Island and Bahrain. The initial results showed the success of pXRF for examining the homogeneity of ceramic potsherds non-destructively. Three distinct compositional groups were observed by means of pXRF. Interestingly, each group is correlated to a distinct pottery tradition. Petrographic analysis was utilized to assess pXRF results and to construct a mineralogical database and obtain information related to ancient techniques. Petrographic thin section analysis was able as was pXRF to discriminate between samples of the early third of the second millennium BC. Furthermore, it was able to provide a qualitative perspective to examine a variation within the Dilmun collection. Along with pXRF, petrographic thin section analysis was successful at creating groups and subgroups with the samples and provided valuable

information about the choice of raw materials, firing technique, and the overall production technology. The variation of temper preparation and clay use supports the existence of independent professionals, but standardized recipes for Dilmun pottery could not be established. Additional discussion on the scale of craft specialization and exchange is provided in the next chapter.

## CHAPTER NINE: CONCLUSION

### 9.1 Introduction

In this study, I have sought to explore the nature of Dilmun's economic role in the trade network of the Arabian Gulf region through the economic activity at strategic sites along the maritime trade routes, like Failaka Island. The Dilmun may have tried to steer the nature of trade in the Arabian Gulf through the dissemination of their native products and the control of the influx of exotic materials. Political authority and elite social groups have been known to assert their authority over their native economy by controlling raw materials, craftsmen, and the flow of goods. Standardization (i.e. styles, ceramic recipes, and preferred raw material sources) of wares is noted as a mark of elite control over craft specialists and their goods. Thus, this study was designed to determine if the Dilmun elite and political authority expressed their status by (1) acquiring non-local pottery, and (2) having a control over internal ceramic craft production.

The influx of non-local wares and the appearance of standardized Barbar wares from Dilmun sites in Kuwait and Bahrain were used as units of analyses for production centers and craft specialization. This synthesis was framed by the question, *Did the Dilmun elite exercise control over both the pottery trade and/or exchange and craft specialization within their territories?* The possible recipe standardization of these wares was used to infer the authority of the Dilmun (Bahrain) elite on Barbar ceramic production in addition to control of a maritime route. Through the analyses of the chemical and mineralogical composition of Barbar pottery,



this study was designed to address the latter questions surrounding standardization and craft specialization throughout the Dilmun region.

The shift in ceramic craft production was parallel with the increasing socio-political complexity of the Dilmun. By the Barbar period, fortifications, temple buildings, planned settlements, burial mounds, and exotic wares appear at Dilmun sites. It was assumed that the technique and unit of analyses may suggest several interpretations, such as (1) Dilmun elites controlled mainland production and the distribution of wares to satellites; (2) alternatively, Dilmun elites controlled only the mainland, not satellites; or (3) Dilmun craft specialists were independent of elites and there was no standardization of ceramic recipes.

In terms of the elemental results, statistical analysis of the pXRF compositional data assigned all Kuwait and Bahrain sherds to one Dilmun group. Other pXRF groups represent different pottery traditions that were circulated and flowed within Dilmun sites during the second millennium BC. Thus, the pXRF was able to differentiate compositionally between and among Dilmun sites on Failaka Island and in Bahrain. However, though the pXRF group was inclusive of all Dilmun types, it did not represent a standardization of clay type and ceramic technique. This compositional homogeneity could reflect a geological homogeneity of Kuwait and Bahrain clay. This would preclude the understanding of any variation among Dilmun ceramics when using pXRF with the analytical settings used in this study. Though there was no standardization of recipes, the uniformity of styles strongly suggests that there was a professional class of potters. Also, these potters may have been unattached and shifted gradually away from a household level of pottery production.

Petrographic thin section results showed that there was variation among Dilmun ceramic potsherds in terms of clay use, firing temperature and raw material preparation. The Dilmun

potters utilized a range of clay types, such as iron-rich, iron-rich and micaceous, and calcareous clay. The variation of firing temperature and technique and the inconsistency of preparing inclusions also suggests some form of non-standardized production. The difference observed was not related to any vessel types or archaeological sites but existed within each site and ceramic ware type. Thus, the standardization of a recipe was not observed either on Failaka or Bahrain at any phases of the early second millennium BC. In addition, non-local sherds were observed in Palace-like structures at F6 and the Al-Khidr site on Failaka Island.

## **9.2 Discussion**

This research has ruled out elite control, whether in Failaka or Bahrain, over Dilmun ceramic artifacts in the Barbar/City II period. Standardization of products is considered as an indication of a centralized professional class at work (Wright 1984). However, the absence of raw material standardization would support the existence of either household level production or an independent class of professionals.

The household is characterized by simple technology and oriented toward self-sufficiency (Rice 2005:184). The household level could produce and extend to manufacture pottery as an investment, but still employ show the use of simple technology. The professional level has different aspects, as the specialists involved may have been independent or attached to the elite and centralized administration. The independent specialist is who could produce goods and services for an unspecified demand that varies according to political, economic, and social conditions (Brumfiel and Earle 1987:5). The attached specialist usually produces goods and service to meet the needs of a patron or elite individual; he/she is usually involved in the manufacture of luxury items and the provisions of the institution (Brumfiel and Earle 1987:5).

The results of this study do not support the Dilmun elites having had control over craft specialization during the early second millennium BC if the findings of this study are representative of pottery assemblages throughout the Dilmun regions. It is possible that the political authority preferred to manage the internal and external flow of pottery by maintaining a favorable relationship with the potters. It is arguable that building an alliance to manage and/or control production was possible. Blanton et al. (1996) divided these control and management strategies into network-based and corporate-based.

In this network-based strategy model, the political authority would maintain relationships with other settlements and population to secure the flow of exotic materials and practice of exchange. It is a wealth-based strategy that transfers the actor to a prestigious status and power as well as gaining regional prominence (Blanton et al. 1996:3). This strategy would be applicable for the sociopolitical and economic system in Harappa and Mesopotamia in which the administration and temple were interested in controlling the production of prestigious materials and obtaining them from different regions. In the corporate-based strategy, the political actors aim to control sources in small-scale networks. It is within a knowledge-based system that the political actor would take action within the local group with the acquisition of individual prestige more than with the maintenance of local-group solidarity. It is similar to Renfrew's (1974:74-79) concept of a "group-oriented chiefdom" in which impressive public works, social egalitarianism, and consuming and producing staple finance are important (Blanton et al. 1996:7).

It seems that the Mesopotamia and Indus Valley administrations exercised both strategies as 'dual process' in the political economy of the Bronze Age. It appears they emerged by empowering external social ties in the trade route and network exchange (network-based strategy); also, by controlling over the staple finance and circulation of subsistence goods

(corporate-base strategy). If the finds of this study are representative of Dilmun pottery, it seems that the Dilmun administration exercised more the corporate-base strategy by maintaining relationships with independent potters to produce the Barbar pottery while the elites and temple may have maintained their control on the pottery circulation and obtaining prestige items or non-local items for their personal use such as Jhuakar pottery or ivory from the Indus Valley. The elites may not have controlled pottery production directly as this was not a very economically beneficial strategy given the widespread availability of clay. However, they probably controlled the distribution of pottery indirectly, through control of what was being traded in pottery and also the overall control of access in and out of walled settlements.

Barbar pottery production and development seems to have occurred independent of elites. This infers that the political institution needed to exert control over the mobilization of labor and goods distribution to the state institutions and personnel. In the staple finance system, the goods are collected from the commoners or land owners by the state and then redistributed to the general population and state personnel for household needs (D'Altroy and Earle 1985). Additionally, the administration may also have controlled the storage of pottery and subsistence goods that served the local economy. In the political economy of a complex society, storage is a vital aspect of distribution by which elites may have exerted control in the management of the network. To the administrative authority, storage is very important because it allows them to control the fluctuation of materials over time and to seek a reliable supply of material (D'Altroy and Earle 1985). Storages or warehouses were usually built in conjunction with administrative and religious centers to supply the community and to meet the demand of ceremonial feasting as has been noted for ancient Babylonia, Egypt and the Andes (D'Altroy and Earle 1985). For example, during the agricultural off-season, war, or an increase in population, the administrative

authority must be able to control the availability and use of the materials to secure the needs of the populace. Therefore, the storage of pottery is important in the subsistence economy, particularly during periods of scarcity.

In general, both pXRF and petrographic analysis results showed that there were very few non-local sherds present at the Palace site of tell F6 in Failaka Island and at Al-Khidr as well. This suggests that the political ruler or elite of Failaka accepted exotic wares on a limited basis. Non-local wares were not prevalent over native Barbar wares even in elite contexts, during the early second millennium BC. The amount of Dilmun vessels on Failaka arguably indicates that Dilmun authorities promoted native potters' products. The Dilmun authorities could have had the same attitude that prevented the prevalence of Mesopotamian and Umm an-Nar pottery, which were dominant in the later third millennium BC. On the other hand, the Failaka Island settlers could have simply had a preference for their native wares over non-locals. Because they were a trade port and smaller than the mainland communities, it may have been difficult for exotic wares to saturate the communities on the island.

It should be noted that the same administration that made the decision to colonize Failaka Island as a Dilmun economic spearhead of the Arabian Gulf was responsible for internal changes (i.e. temples, walled complexes, elite burial mounds, etc.). The growth of this institution was contemporary with the presence of the seven Indus weights inside a structure within Qala'at, the walled complex; they were distributed in municipal offices (Bibby 1969:335; Højlund 1994b:471). The rare distribution of Harappan-style weights among Dilmun sites and the accumulation of seals at the house in Saar support a Dilmun authority curtailing exotic products. This growth of the political institution seemingly hindered any direct maritime trade between Ur and Magan. After the end of the Ur III dynasty (2028-2004 BC), Magan was no longer

mentioned in Mesopotamian records. After controlling Failaka, the Dilmun authority utilized this island as a trading point or emporium (Weisgerber 1986:138-139). The island was pivotal to the control of the maritime route of the southern part of the Arabian Gulf in which Magan/Oman was the copper supplier to Mesopotamia. It is the time of Dilmun control over the Arabian Gulf from Failaka to Qatar, breaking direct contact between Magan and Mesopotamia.

### **9.3 The Future**

Ceramic production is an avenue of study that has not been exhausted. Investigating the development of ceramic production, archaeometrically, has the potential to explore individual agency. The potter's decision to utilize sophisticated techniques in order to produce a better quality ware, to save time, to respond to market demand, or to compete with a rival are all aspects of ceramic production. At the end of the Qala'at II phase, ca. 1800 BC, an increase of turntable pottery was observed, particularly in large shapes (Højlund 1994b:427). This innovation in large pottery required an improvement of potters' skills and efficient tools to turn the wheel and save time. The potters might have become more selective in the clay they used and more careful about the temper preparation, such as selecting small inclusions and controlling the fire (Sinopoli 1991:101).

Furthermore, Qala'at IIa-c pottery is worth being studied in the future along with Barbar Temple III and Failaka Period 2 wares. The Qala'at II period is marked by gigantic royal tombs in Bahrain and is a period of diplomatic contact between the king of Assyria and the 'king' of Dilmun whose officers were in Mesopotamia, ca. 1800 BC (Højlund 2007; Potts 1990:185). Also, in Kuwait, the Al-Khidr site has materials that suggest it was a redistribution center or a warehouse. The recoveries from this site included massive re-ridge storage jars, metal and stone

tools, and some raw materials (e.g. hematite, sulfur); also, the concentration of a high number of stamp seals with a high number of large red-ridge storage jars in the KH-1 mound suggests that Al-Khidr was a redistribution center or a warehouse (Benediková and Barta 2010:54-55).

Exploring craft specialization and political economic change in Dilmun may develop further from multiple perspectives in addition to stylistic and archaeometric studies. The use of experimental archaeology and ethnographic information (ethnoarchaeology) are powerful tools to make analogical assessments of ceramic production. These approaches seemed very useful for understanding bead, lapis lazuli, bangle and ornament industries in the Indus Valley (Kenoyer 1986, 1996a). Ethnoarchaeological information of pottery production in Pakistan was very useful to understand ceramic production and marketing. It was carried out based on kin networks and reciprocal exchange between potters and agriculturalists (Kenoyer 1996b). Today, ceramic production is rarely practiced in the Arabian Gulf, particularly since the influx of oil income has resulted in the abandonment of the traditional craft industries (e.g. textiles, boat building).

However, during my visit to Bahrain in 2007, there was a pottery workshop in A'ali city that was sponsored to promote the traditional products and skills of ancient Bahrain. An elder, who praised the high quality of A'ali clay, used a turntable '*g'chalahk*' to make his pottery. In response to the visitors' questions, he stated that the pottery must be left for two days to dry and then fired in the kiln '*dogha*' for four days. Along with an experimental approach, a systematic ethnographic study of Bahrain pottery production would strengthen our understanding about ancient craft practice and processes.

In the future, researchers will need to conduct ethnographic and ethno-archaeological studies to help in the process of resolving questions about the past. Also, such projects would encourage the community to participate in the generation of cultural knowledge and the

preservation of sites. The participation of community members in the understanding of the work and process of their own traditional products can contribute to understanding their own history and increase their sense of national pride.

The role of anthropological archaeology can go beyond the involvement of young people in cleaning samples, as in this research. There is a mutual benefit for scholars and laymen alike to answer their research questions and to give the community a voice of understanding their past. In addition to pushing a theoretical boundary and instrumental application, this research can be a window for a larger enterprise that connects the community to their history and makes anthropological archaeology relevant to them. Dilmun pottery, stamp seals, burial mounds, etc. are the pathway to perform applied archaeology. It is the responsibility of scholars to educate and to help the community to understand the past.

As Bronze Age Barbar wares were an expression of the identity, craftsmanship, and the preference of the Dilmun people in the past, they can be the same for descendant communities today. This sense of affinity is necessary today in Kuwait and other Gulf countries. The influx of oil income has caused so many of the drastic changes in the society that have disconnected people from their heritage and identity.

Applied archaeology can foster a relationship between community members, educators, and anthropologists. Participating in experiments to recreate traditional products, like Barbar wares, using traditional methods and materials can revive the craftsmanship amongst the descendant communities. Partnerships with educators can foster new learning opportunities for students and practical training for an emerging labor force. Also, fostering communal participation in emergency extractions to rescue sensitive materials, general excavations, the



restoration of historical buildings, and the conservation of cultural materials are essential to reinvigorate the Kuwaiti identity.

Applied archaeology can be helpful to make Failaka, or Kuwait in general, an emporium as it functioned four thousand years ago. Positioning itself as a transit depot empowered the state of Dilmun economically and socially. Instead of depending on a single natural resource as a base for its economy, Kuwait could create economic goals that include investments in traditional craftsmanship, heritage tourism and the development of a transit economy. As the world moves towards the use of clean-energy alternatives (i.e. hydroelectricity, wind turbines, etc.), fossil fuel economies will need to shift to other industries to survive. A revival of traditional crafts and the kin-based work regimes could solve unemployment issues along with the overall economic shifts. These developments require understanding the expertise of archaeologists that know the landscape of Kuwait, such as traditional resources, land use, and where projects can be launched with a minimal impact on the environment and biodiversity.

## REFERENCES

- Adams, Robert  
1974 Anthropological Perspectives on Ancient Trade. *Current Anthropology* 15(3):239-258.
- Aimers, J, Dori F., and Aaron S.  
2012 Handheld XRF Analysis of Maya Ceramics: A Pilot Study Presenting Issues Related to Quantification and Calibration. *In Studies in Archaeological Science: Handheld XRF for Art and Archaeology* Aaron Shugar and Jennifer Mass., ed. pp. 423-448. Leuven: Leuven University Press.
- Akkermans, Peter, and Kim Duistermaat  
1997 Of Storage and Nomads – The Sealings from Late Neolithic Sabi Abyad, Syria. *Paléorient* 22:17-44.
- Al-Bader, Sulaiman  
1978 mantaqat al khalij al arabi khilal il alfin il thani wal awal qabl al milad (The Arabian Gulf Region through the Second and First Millennium BC). Kuwait: author.
- Alizadeh, Abbas  
2008 Chogha Mish II: The Development of a Prehistoric Regional Center in Lowland Susiana, Southwestern Iran. Chicago: The Oriental Institute of the university of Chicago.
- Algaze, Guillermo  
1989 The Uruk Expansion: Cross Cultural Exchange in Early Mesopotamian Civilization. *Current Anthropology* 30(5):571-608.  
  
1993 *The Uruk World System: The Dynamics of Expansion of Early Mesopotamian Civilization*. Chicago: University of Chicago Press.  
  
2001 The Prehistory of Imperialism: The Case of Uruk period Mesopotamia. *In Uruk Mesopotamia and Its Neighbors: Cross-Cultural Interactions in the Era of State Formation*. Mitchell S. Rothman, ed. pp. 27-83. Santé Fe: School of American Research Press.
- Allen, Mitchell  
1992 The Mechanism of Underdevelopment: An Ancient Mesopotamia Example. *Review* 15:453-476.

- Alsharhan, A.S., and A.E.M. Nairn  
2003 *Sedimentary Basins and Petroleum Geology of the Middle East*. Amsterdam: Elsevier.
- Alster, Bendt  
1983 Dilmun, Bahrain, and the Alleged Paradise in the Sumerian Myth and Literature. *In* Dilmun: New Studies in the Archaeology and Early History of Bahrain. Daniel Potts, ed. pp. 39-74. Berlin: Reimer.
- Ames, Kenneth  
1995 Chiefly Power and Household Production on the Northwest Coast. *In* Foundations of Social Inequality. T. Douglas Price and Gary M. Feinman, eds. pp. 155-187. New York: Plenum Press.
- Andersen, H. Hellmuth, and Flemming Højlund  
2003 *The Barbar Temples, Vol. 1*. Moesgård: Jutland Archaeological Society.
- Arnold, Dean E.  
1999 Advantages and Disadvantages of Vertical-Half Molding Technology: Implications for Production Organization. *In* Pottery and People: A Dynamic Interaction. James Skibo and Gary M. Feinman, eds. pp. 59-80. Salt Lake City: The University of Utah Press.
- Ashkanani, Hasan, and Robert H. Tykot  
2013 Interregional Interaction and Dilmun Power in the Bronze Age: A Provenance Study of Ceramics from Bronze Age Sites in Kuwait and Bahrain Using Non-Destructive pXRF Analysis. *In* Archaeological Chemistry VIII. Ruth A. Armitage and James H. Burton, eds. pp. 245-267. ACS Symposium Series 1147. Washington, DC: American Chemical Society.
- Astour, Michael C.  
2002 A Reconstruction of the History of Ebla. *In* Eblaitica. Cyrus Gordon and Gary Rendsburg, eds. pp. 57-196. Winona Lake, IN.: Eisenbrauns.
- Azam, Shahid  
2006 Large-scale odometer for assessing swelling and consolidation behavior of Al-Qatif clay 85 *In* Expansive Soils: Recent Advances in Characterization and Treatment. Amer A. Al-Rawas and Mattheus F.A. Goosen, eds. pp. 85-100. UK: Taylor & Francis.
- Badreshany, Kamal, and Hermann Genz  
2009 Pottery Production on the Northern Lebanese Coast during the Early Bronze Age II–III: The Petrographic Analysis of the Ceramics from Tell Fadous-Kfarabida. *BASOR* 335:51-83.

- Benediková, Lucia  
 2010 *Al-Khidr 2004-2009; Primary Scientific Report on the Activities of the Kuwait-Slovak Archaeological Mission*. Kuwait City: NCCAL.
- Benediková, Lucia, and Peter Barta  
 2008 Kuwaiti-Slovak Archaeological Mission: Finds from Al-Khidr.  
<http://www.kuwaitarchaeology.org/al-khidr-finds.html>, accessed January 26, 2009.
- Berman, Judith  
 1987 Ceramic Production and its Implications for the Sociopolitical Organization of the Suse Phase Susiana. *Paléorient* 13(2):47-60.
- Bhan, Kuldeep, Massimo Vidale, and Jonathan M. Kenoyer  
 1994 Harappan Technology: Theoretical and Methodological Issues. *Man and Environment* 19:141-157.
- Bibby, Geoffrey  
 1969 *Looking for Dilmun*. New York: Alfred Knope.
- Blackman, M. James, Gil Stein, and Pamela B. Vandiver  
 1993 The Standardization Hypothesis and Ceramic Mass Production: Technological, Compositional, and Metric Indexes of Craft Specialization at Tell Leilan, Syria. *American Antiquity* 58(1):60-80.
- Blackman, M. James, Sophie Mery, and Rita P. Wright  
 1989 Production and Exchange of Ceramics on the Oman Peninsula from the Perspective of Hili. *Journal of Field Archaeology* 16(1):61-77.
- Blanton, Richard E., Gary Feinman, Stephen A. Kowalewski and Peter N. Peregrine  
 1996 A Dual-Processual Theory for the Evolution of Mesoamerican Civilization. *Current Anthropology* 37(1):1-14.
- Bohannon, Paul, and George Dalton, eds.  
 1962 *Markets In Africa*. Evanston: Northwestern University Press.
- Bravo, Francesco Del  
 2013 The Luristan-Hamrin Cultural Sphere (4th - 3rd Millennium BC). Pottery Identity as Intra-Societies Interactions. In *Identity and Connectivity*, Anacleto D' Agostino Luca Bombardieri, Guido Guarducci, Valentina Orsi and Stefano Valentini, ed. pp. 3-10. Oxford: Archaeopress.
- Breuil, Jean-Yves  
 1999 The World's Largest Prehistoric Cemetery. In *Bahrain: The Civilisation of the Two Seas*. Pierre Lombard, ed. pp. 56-71. Paris: Institut du Monde Arabe.

- Brumfiel, Elizabeth, and Timothy Earle  
1987 Specialization, Exchange, and Complex Societies: An Introduction. *In* Specialization, Exchange, and Complex Societies. Elizabeth Brumfiel and Timothy Earle, eds. pp. 1-9. London: Cambridge University Press.
- Calvet, d' Yves, and Jacqueline Gachet  
1990 *Failaka: Fouilles Francaises (1986-1988)*. Lyon: Maison de l'Orient Meditteranean.
- Calvet, Yves, and Marielle Pic  
1986 Un nouveau batiment de l' Age du Bronze sur le Tell F6. *In* Failaka: Fouilles Francaises 1984-1985. Yves Calvet and Jean-François Salles, eds. pp. 13-87. Lyon: Maison de l'Orient Meditteranean.
- Cannon, Jaques, Harriet Crawford, Mark Tobi, Armelle Charrie-Duhaut,, Dan Jarbie, Pierre Albrecht, and Kirsty Norman  
2005 A Comparative Geochemical Study of Bituminous Boat Remains from H3, As-Sabiyah (Kuwait), and RJ-2, Ra's al-Jinz (Oman). *Arabian Archaeology and Epigraphy* 16(21-66).
- Cardi, Beatrice de  
1986 Some Aspects of Neolithic Settlement in Bahrain and Adjacent Regions. *In* Bahrain Through the Ages the Archaeology. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 87-93. London: KPI Limited.
- Carter, Robert A.  
2002 Ubaid-period Boat Remains from As-Sabiyah: Excavations by the British Archaeological Expedition to Kuwait. *In* Proceedings of the Seminar for Arabian Studies. pp. 13-30.  
  
2006 Boat Remains and Maritime Trade in the Persian Gulf During 6th and 5th Millennia B.C. *Antiquity* 80(52-63).
- Carter, Robert A., and Harriet Crawford  
2003 The Kuwait-British Archaeological Expedition to As-Sabiyah: Report on the Fourth Season's Work. *Iraq* 65:77-90.
- Carter, Robert A., Harriet Crawford, Simeon Mellalieu, and Dan Barret  
1999 The Kuwait/British Archaeological Expedition to As-Sabiyah: Report on the First Season's Work. *Iraq* 61:43-58.
- Carter, Robert A., and Graham Philip  
2010 Deconstructing the Ubaid. *In* Beyond the Ubaid: Transformation and Integration in the Late Prehistoric Societies of the Middle East. Robert A. Carter and Graham Philip, eds. pp. 1-22. Chicago: The Oriental Institute of the University of Chicago.

- Catling, Hector W., E. E. Richards, and A. E. Blin-Stoyle  
1963 Correlations between composition and provenance of Mycenaean and Minoan pottery. *Annual of the British School at Athens* 58:95-115.
- Champion, Timothy, and Sara Champion  
1986 Peer Polity Interaction in the European Iron Age. *In* Peer Polity Interaction and Social-Political Change. Colin Renfrew and John Cherry, eds. pp. 59-68. Cambridge: Cambridge University Press.
- Chase-Dunn, Christopher, and Thomas D. Hall  
1993 Comparing World-Systems: Concepts and Working Hypotheses. *Social Forces* 71(4):851-886.  
  
1997 *Rise and Demise: Comparing World-Systems*. Boulder: Westview Press.
- Chayes, Felix  
1956 *Petrographic Modal Analysis*. New York: Wiley.
- Chen, Tiemei, George Rapp, Zhichun Jing, and Nu He  
1999 Provenance Studies of the Earliest Chinese Protoporcelain Using Instrumental Neutron Activation Analysis. *Journal of Archaeological Science* 26:1003-1015.
- Childe, V. Gordon  
1950 The Urban Revolution. *Town Planning Review* 21:3-17.
- Claessen, Henri J., and Pieter van de Velde  
1991 Introduction. *In* Early State Economics. Henri J. Claessen and Pieter van de Velde, eds. pp. 1-29. New Jersey: Transaction.
- Clark, Grahame  
1952 *Prehistoric Europe: The Economic Basis*. London: Methuen.
- Clark, John, and Michael Blake  
1993 The Power of Prestige: Competitive Generosity and the Emergence of Rank Societies in Lowland Mesoamerica. *In* Factional Competition in the New World. Elizabeth Brumfiel and John Fox, eds. pp. 17-30. Cambridge: University of Cambridge Press.
- Cleuziou, Serge  
1986 Dilmun and Makkan During the Third and Early Second Millennia B.C. *In* Bahrain Through the Ages the Archaeology. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 143-155. London: KPI Limited.
- Cohen, Abner  
1969 *Custom and Politics in Urban Africa: A Study of Hausa Migrants in Yoruba Towns*. Berkeley: University of California Press.

- 1971 Cultural Strategies in the Organization of Trading Diasporas. *In* The Development of Indigenous Trade and Markets in West Africa. Claude Meillassoux, ed. pp. 266-281. London: Oxford University Press.
- Comodi, P., M. Bernardi, A. Bentivoglio, G. D. Gatta, and P. Zanazzi  
2004 Production and Technology of Glazed Ceramics from the Middle Ages Found in the Saepinum Territorium (Italy): A Multimethodic Approach. *Archaeometry* 46:405-419.
- Cornwall, Peter  
1999 [1946] *Dilmun: The History of Bahrein Island Before Cyrus*. M. Khuzai, transl. Bahrain: Bahrain Information services.
- Costin, Cathy L.  
1991 Craft Specialization: Issues in Defining, Documenting, and Explaining the Organization of Craft. *In* Craft Specialization: Issues in Defining, Documenting, and Explaining the Organization of Craft. Michael B. Schiffer, ed. pp. 1-56. Tucson: University of Arizona Press.
- Craig, Nathan, Robert J. Speakman, Rachel S. Popelka-Filcoff, Michael D. Glascock, J. David Robertson, M. Steve Shakley, and Mark S. Aldenderfer  
2007 Comparison of XRF and PXRF for Analysis of Archaeological Obsidian From Southern Peru. *Journal of Archaeological Science* 34:2012-2024.
- Crawford, Harriet  
1998 *Dilmun and its Gulf Neighbours*. Cambridge: Cambridge University Press.
- D'Altroy, Terence N., and Timothy K. Earle  
1985 Staple Finance, Wealth Finance, and Storage in the Inca Political Economy. *Current Anthropology* 26:187-206.
- D'Altroy, Terence N., and Ronald L. Bishop  
1990 The Provincial Organization of Inka Ceramic Production. *American Antiquity* 55(1):120-138.
- Dales, George F.  
1991 Some Specialized Ceramic Studies at Harappa. *In* Harappa Excavations 1986-1990 A Multidisciplinary Approach to Third Millennium Urbanism. Richard H. Meadow, ed. pp. 61-69. Madison: Prehistory Press.
- Dales, George F. and Jonathan M. Kenoyer  
1986 *Excavations at Mohenjo Daro, Pakistan: The Pottery*. Univ. Museum Monograph 53. Philadelphia.  
1990 Excavation at Harappa-1998. *Pakistan Archaeology* 24:68-176.

- 1991 Summaries of Five Seasons of Research at Harappa (District Sahiwal, Punjab, Pakistan)1986-1990. *In* Harappa Excavations 1986-1990 A Multidisciplinary Approach to Third Millennium Urbanism. Richard H. Meadow, ed. Madison: Prehistory Press.
- Dani, Ahmad Hasan  
1986 Bahrain and the Indus Civilization. *In* Bahrain through the ages the Archaeology. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 383-388. London: KPI Limited.
- David-Cuny, Hélène, and Johanne Azpeitia  
2012 *Failaka Seals Catalogue Vol. 1*. Kuwait NCCAL.
- Davis, M, Thomas Jackson, M. Shackley, Timothy Teague, and Joachim Hampel  
2011 Factors Affecting the Energy-Dispersive X-Ray Fluorescence (EDXRF) Analysis of Archaeological Obsidian. *In* X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology., M. Steven Shackley, ed. pp. 45-63. New York: Springer.
- Day, Peter M., Evangelia Kiriati, Alexandra Tsolakidou, and Vassilis Kilikoglou  
1999 Group Therapy in Crete: A Comparison Between Analyses by NAA and Thin Section Petrography of Early Minoan Pottery. *Journal of Archaeological Science* 26:1025-1036.
- Dercksen, Jan G.  
1996 *The Old Assyrian Copper Trade in Anatolia*. Istanbul: Nederlands Historisch-Archaeologisch Institute te Istanbul.
- Doornkamp, John Charles, Denys Brunsden, and David K. C. Jones, eds.  
1980 *Geology, Geomorphology and Pedology of Bahrain*. Norwich: Geo Abstracts.
- During Caspers, Elisabeth  
1994 Further Evidence for 'Central Asian' Materials From the Arabian Gulf. *Journal of the Economic and Social History of the Orient* 37(1):33-53.
- Earle, Timothy K.  
1977 A Reappraisal of Redistribution. *In* Exchange Systems in Prehistory. Timothy K. Earle and Jonathon E. Ericson, eds. pp. 213-232. New York: Academic.
- Edens, Christopher  
1986 Bahrain and the Arabian Gulf During the Second Millennium B.C.: Urban Crisis and Colonialism. *In* Bahrain Through the Ages the Archaeology. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 195-216. London: KPI Limited.
- 1987 A Late Second Millennium B.C. Purple Dye Industry in Qatar (Arabian Gulf): Archaeological and Historical Interpretations, PhD dissertation, Department of Anthropology, Harvard University.



- 1992 Dynamics of Trade in the Ancient Mesopotamian “World System”. *American Anthropologist* 94(1):118-139.
- 1994 On the Complexity of Complex Societies: Structure, Power and Legitimation in Kassite Babylonia. *In* Chiefdoms and Early States in the Near East: the Organizational Systematics of Complexity. Gil Stein and Mitchell Rothman, eds. pp. 209-223. Madison: Prehistory Press.
- 1999 Khor Ile-Sud, Qatar: The Archaeology of Late Bronze Age Purple-Dye Production in the Arabian Gulf. *Iraq* 61:71-88.
- Ekholm, Kajsas, and Jonathan Friedman  
 1982 ‘Capital’ Imperialism and Exploitation in Ancient World Systems. *Review* 4:87-109.
- Evans, Robert K.  
 1978 Early Craft Specialization: An Example from the Balkan Chalcolithic. *In* Social Archeology: Beyond Subsistence and Dating. Charles L. Redman, Mary J. Berman, Edward V. Curtin, William T. Langhorne, Jr., Nina M. Versaggi, and Jeffery C. Wanser, eds. pp. 113-129. New York: Academic Press, Inc.
- Feinman, Gary M.  
 1999 Rethinking Our Assumptions: Economic Specialization at the Household Scale in Ancient Ejutla, Oaxaca, Mexico. *In* Pottery and People: A Dynamic Interaction. James M. Skibo and Gary M. Feinman, eds. pp. 81–98. Salt Lake City: University of Utah Press.
- Feinman, Gary M., Stephen A. Kowalewski, Sherman Banker, and Linda Nicolas  
 1992 Ceramic Production and Distribution in Late Postclassic Oaxaca: Stylistic and Petrographic Perspectives. *In* Ceramic Production and Distribution: An Integrated Approach. George J. Bey III and Christopher A. Pool, eds. pp. 235-259. Boulder: Westview Press.
- Galaty, Michael, Dimitri Nakassis, and William Parkinson  
 2011 Redistribution in Aegean Palatial Societies. *AJA* 115(2):175-244.
- Galvin, Kathleen F.  
 1987 Forms of Finance and Forms of Production: The Evolution of Specialized Livestock Production in the Near East. *In* Specialization, Exchange, and Complex Societies. Elizabeth M. Brumfiel and Timothy K. Earle, eds. pp. 119-129. London: Cambridge University Press.

Ghazal, Royal, Nicholas Kouchoukos, Robert J. Speakman, Michael Glasscock, and Christophe Descantes

2008 Production Zone Sourcing and Intraregional Exchange of Ceramics in The Fourth-Millennium B.C. Susiana Plain: A Case Study. *In* Chogha Mish Vol. II. The Development of a Prehistoric Regional Center in Lowland Susiana, Southwestern Iran: Final Report on the Last Six Seasons of Excavations, 1972–1978. Abbas Alizadeh, ed. Chicago: The Oriental Institute.

Goodale, N., D.G. Bailey, G.T. Jones, C. Prescott, E. Scholz, N. Stagliano, and C. Lewis  
2012 pXRF: A Study of Inter-instrument Performance. *Journal of Archaeological Science* 39:875-883.

Goren, Y., H. Mommsen, and J. Klinger  
2011 Nondestructive Provenance Study of Cuneiform Tablets using Portable X-Ray Fluorescence (pXRF). *Journal of Archaeological Science* 38:684-696.

Grave, D., D. T. Potts, N. Yassi, W. Reade, and G. Bailey  
1996 Elemental Characterization of Barbar Ceramics from Tell Abraq. *Arabian Archaeology and Epigraphy* 7:177-187.

Gray, Richard, and David Birmingham  
1970 *Precolonial African Trade*. London: Oxford University Press.

Green, Elizabeth  
2007 Analysis of Archaeological Sampling Methods Using the Complete Surface Data from the Pirque Alto Site in Cochabamba, Bolivia. *Journal of Undergraduate Research* 1-22.

Hall, Thomas, P. Nick Kardulias, and Christopher Chase-Dunn  
2011 World-Systems Analysis and Archaeology: Continuing the Dialogue. *Journal of Archaeological Research* 19:233-279.

Hallet, Jessica  
1999 Trade and Innovation: The Rise of The Pottery Industry in Abbasid Basra, Department of Oriental Studies, University of Oxford.

Hatcher, Helen, Alexander Kaczmarczyk, Agnes Scherer, and Robin P. Symonds  
1994 Chemical classification and Provenance of some Roman Glazed Ceramics. *American Journal Archaeology* 98:431-456.

Healey, Elizabeth  
2010 Ubaid Lithics Revisited: Their Significance for the Interpretation of Ubaid Society. *In* Beyond the Ubaid: Transformation and Integration in the Late Prehistoric Societies of the Middle East. Robert A. Carter and Graham Philip, eds. pp. 181-200, Vol. Studies in Ancient Oriental Civilization. Chicago: The Oriental Institute of the University of Chicago.

Hein, Anno, Hans Mommsen and J. Maran

1999 Element Concentration Distributions and Most Discriminating Elements for Provenancing by Neutron Activation Analysis of Ceramics from Bronze Age Sites in Greece. *Journal of Archaeological Science* 26:1053-58.

Helwing, Barbara

1999 Cultural Interaction at Hassek Höyük, Turkey: New Evidence from Pottery Analysis. *Paléorient* 25(1):91-99.

Herskovits, Melville

1937 The Significance of the Study of Acculturation for Anthropology. *American Anthropologist* 39:259-264.

Herz, Norman, and Ervan Garrison

1998 *Geological Methods for Archaeology*. Oxford: Oxford University Press.

Hein, A., H. Mommsen, and J. Maran

1999 Element Concentration Distributions and Most Discriminating Elements for Provenancing by Neutron Activation Analysis of Ceramics from Bronze Age Sites in Greece. *Journal of Archaeological Science* 26:1053-58.

Hirth, Kenneth

1978 Interregional Trade and the Formation of Prehistoric Gateway Communities. *American Antiquity* 43:35-45.

1996 Political Economy and archaeology: perspective on Exchange and production. *Journal of Archaeological Research* 4:203-230.

2006 Market Forces or State Control: The Organization of Obsidian Craft Production in a Civic-Ceremonial Context. In *Obsidian Craft Production in Ancient Central Mexico*. Kenneth G. Hirth, ed. pp. 179–201. Salt Lake City: University of Utah Press.

2009 Housework and Domestic Craft Production: An Introduction. In *Housework: Craft Production and Domestic Economy in Ancient Mesoamerica*. Kenneth G. Hirth, ed. pp. 1–12. New York: Wiley-Blackwell.

Hodder, Ian

1982 *Symbols in Action: Ethnoarchaeological Studies of Material Culture: New Studies in Archaeology*. Cambridge: Cambridge University Press.

1990 *The Domestication of Europe: Structure and Contingency in Neolithic Societies*. Oxford: Blackwell.

1992 *Theory and Practice in Archaeology*. London: Routledge.

- Hoeck, Volker, Corina Ionescu, Lucretia Ghergari, and Carmen Precup  
2009 Towards Mineralogical and Geochemical Reference Groups for Some Bronze Age Ceramics from Transylvania (Romania). *Studia Universitatis Babes-Bolyai* 54(2):41-51.
- Hole, Frank  
1987 Archaeology of Iran Village Period. In *The Archaeology of Western Iran; Settlement and Societies from Prehistory to the Islamic Conquest*, Frank Hole, ed. pp. 29-78. Washington D.C: Smithsonian Institution Press.
- Howard-Carter, Theresa  
1972 The Johns Hopkins University Reconnaissance Expedition to the Arab Iranian Gulf. *The American Schools of Oriental Research* 207(Oct):6-40.
- Højlund, Flemming  
1986 The Chronology of City II and III at Qal'at al-Bahrain. In *Bahrain through the Ages the Archaeology*. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 217-224. London: KPI Limited.
- 1987 *Failaka/Dilmun: The Bronze Age Pottery. Volume 2*. Aarhus: Aarhus University Press.
- 1989 The formation of the Dilmun State and the Amorite Tribes. *Proceedings of the Seminar for Arabian Studies* 19:46-57.
- 1993 The Ethnic Composition of the Population of Dilmun. *PSAS* 1-8.
- 1994a Pottery from the Pre-Barbar and Barbar Periods (I-II). In *Qala'at al-Bahrain: The Northern City Wall and The Islamic Fortress*. Flemming Højlund and H. Hellmuth Andersen, eds. pp. 73-178. Aarhus: JASP.
- 1994b Summary and Conclusions. In *Qala'at al-Bahrain: The Northern City Wall and The Islamic Fortress*. Flemming Højlund and H. Hellmuth Andersen, eds. pp. 463-481. Aarhus: JASP.
- 2003 Pottery and the Dating of the Temple Phases. In *The Barbar Temples, Vol. 1.*, H. Hellmuth Andersen and Flemming Højlund, eds. pp. 209-254. Moesgård: JASP.
- 2007 *The Burial Mounds of Bahrain: Social Complexity in the Early Dilmun*. Aarhus: JASP.
- 2012 The Dilmun temple on Failaka, Kuwait. *Arabian Archaeology and Epigraphy* 32(2):165–173.

- Højlund, Flemming, and H. Hellmuth Andersen  
1994 *Qala'at al-Bahrain: The Northern City Wall and The Islamic Fortress*. Aarhus: JASP.
- Hughes, M. J., K.J. Matthews, and J. Portal  
1999 Provenance Studies of Korean Celadons of the Koryo Period by Neutron Activation Analysis. *Archaeometry* 41(2):287-310.
- Johnson, Allen W., and Timothy K. Earle  
1987 *The Evolution of Human Societies: From Foraging Group to Agrarian State*. Stanford: Stanford University Press.
- Johnson, Gregory  
1975 Locational Analysis and Investigation of Uruk Local Exchange System. In *Ancient Civilization and Trade*. Jeremy Sabloff and C.C. Lamberg-Karlovsky, eds. pp. 285-339. Albuquerque: University of New Mexico Press.
- Jones, R. E.  
1986 *Greek and Cypriot Pottery: A Review of Scientific Studies*. Athens: Fitch Laboratory Occasional Paper 1.
- Junker, Laura L.  
1990 The Organization of Inter-regional and Long-distance Trade in Prehistoric Philippine Complex Societies. *Asian Perspectives* 29:167-209.
- Karydas, A.G., D. Kotzamani, R. Bernard, J.W. Barrandon, and Ch. Zarkadas  
2004 A Compositional Study of a Museum Jewellery Collection (7th–1st BC) by Means of a Portable XRF Spectrometer. *Nuclear Instruments and Methods in Physics Research Section B* 226:15-28.
- Kelley, Katherine A., Terry Plank, John Ludden, and Hubert Staudigel  
2003 Composition of Altered Oceanic Crust at ODP Sites 801 and 1149. *Geochemistry Geophysics Geosystems* 4:1-21.
- Kenoyer, Jonathan M.  
1984 Shell Working Industries of the Indus Civilization: A Summary. *Paleorient* 10(1):49-63.  
  
1986 The Indus Bead Industry: Contributions to Bead Technology. *Ornament* 10(1):18-23.  
  
1991 Urban Process in the Indus Tradition: A Preliminary Model from Harappa. In *Harappa Excavations to Third Millennium Urbanism*. Richard H. Meadow, ed. pp. 29-60. Madison: Prehistory Press.  
  
1996a Bead Replicas An Alternative to Antique Bead Collecting. *Ornament* 20(2):68-71.

- 1996b Craft Traditions of the Indus Civilization and Their Legacy in Modern Pakistan. *Lahore Museum Bulletin* IX(2):1-8.
- 1997 Trade and Technology of the Indus Valley: New Insight from Harappa, Pakistan. *World Archaeology* 29(2):226-280.
- 2008a Indus and Mesopotamian Trade Networks: New Insights from Shell and Carnelian Artifact. *In* Intercultural Relations between South and Southwest Asia: Studies in Commemoration of E.C.L. During Caspers (1934-1996). Eric Olijdam and Richard H. Spoor, eds. pp. 19-28. Oxford: British Archaeological Reports.
- 2008b Indus Civilization. *In* Encyclopedia of Archaeology. Deborah M. Pearsall, ed. pp. 715-733. New York: Academic Press.
- Salem, Khaled
- 2006a Gazirat Failaka fe kitabat il rahalin wo'il mo' arikin wo'il shu'ara (Failaka Island in explorers, historians, and poets' literatures). Kuwait: author.
- 2006b Gazirat Failaka ashhar el gozor il kuwaitia (Failaka Island: The most famous Kuwaiti Island). Kuwait: author.
- Killick, Robert, and Jane Moon
- 2005 *The Early Dilmun Settlement at Saar*. Ludlow: Archaeological International.
- Kjaerum, Poul
- 1980 Seals of « Dilmun Type » from Failaka, Kuwait. *Proceedings of the Seminar for Arabian Studies* 10:45- 53.
- 1983 *The Stamp and Cylinder Seals. Volume 1:1*. Aarhus: JASP.
- 1986 The Dilmun Seals as Evidence of Long Distance Relations in the Early Second Millennium B.C. *In* Bahrain Through the Ages the Archaeology. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 269-277. London: KPI Limited.
- 1999 The Hidden Art of Dilmun: The Stamp-Seals. *In* Bahrain: The Civilisation of the Two Seas, Pierre Lombard, ed. pp. 115-120. Paris: Institut du Monde Arabe.
- Kohl, Philip L.
- 1987a The Ancient Economy, Transferable Technologies and the Bronze Age World System: A View from the Northwestern Frontier of the Ancient Middle East. *In* Centre and Periphery in the Ancient World. Michael Rowlands, Mogens Larsen, and Kristian Kristiansen, eds. pp. 13-24. Cambridge: Cambridge University Press.
- 1987b The Use and Abuse of World Systems Theory: The Case of the Pristine West Asian State. *In* Advances in Archaeological Method and Theory. Michael B. Schiffer, ed. pp. 1-35. San Diego: Academic Press.

Kowalewski, Stephen A.

1996 Clout, Corn, Copper, Core-Periphery, Culture Area. *In* Pre-Columbian World Systems. Peter N. Peregrine and Gary M. Feinman, eds. pp. 1-10. Madison: Prehistory Press.

Krader, Lawrence

1968 *Formation of the State*. New Jersey: Prentice-Hall.

Kreiter, Attila, György Szakmány, and Miklós Kázmér

2009 Ceramic Technology and Social Process in Late Neolithic Hungary. *In* Interpreting silent artefacts: petrographic approaches to archaeological ceramics. Patrick S. Quinn, ed. pp. 101-119. Oxbow: Oxford.

Kulkarni, Vishwas N.

1985 Physical Geology of Gujarat. *Navnirman* 2:1-8.

Lamberg-Karlovsky, C.C.

1972 Trade Mechanism in Indus-Mesopotamian Interrelation. *Journal of the American Oriental Society* 92(2):222-229.

1975 Third Millennium Modes of Exchange and Modes of Production. *In* Ancient Civilization and Trade. Jeremy Sabloff and C.C. Lamberg-Karlovsky, eds. pp. 341-367. Albuquerque: University of New Mexico Press.

Larsen, Curtis

1983 *Life and Land Use on the Bahrain Islands: The Geoarcheology of an Ancient Society*. Chicago: The University of Chicago Press.

Larsen, Mogens

1976 *The Old Assyrian City-State and its Colonies*. Copenhagen: Academic.

Laursen, Steffen

2008 Early Dilmun and Its Rulers: New Evidence of the Burial Mounds of the Elite and the Development of Social Complexity, c. 2200–1750 BC. *Arabian Archaeology and Epigraphy* 19:155–166.

2011 Mesopotamian Ceramics from the Burial Mounds of Bahrain, c.2250-1750 BC. *Arabian Archaeology and Epigraphy* (22):32-47.

Leeds, Anthony

1968 The Port of Trade in Pre-European India as an Ecological and Evolutionary Type. *In* Proceedings of the 1961 Spring Meeting of the American Ethnological Society, pp. 26-48.

- Liritzis, I., S. Drakonaki, A. Vafiadou, A. Sampson, and T. Boutsika  
 2002 Destructive and Nondestructive Analysis of Ceramics, Artefacts, and Sediments of Neolithic Ftelia (Mykonos) by Portable EDXRF Spectrometer: First Results. *In* The Neolithic Settlement at Ftelia, Mykonos, A. Sampson, ed. pp. 251-272.
- Liverani, Mario  
 1987 The Collapse of the Near Eastern Regional System at the End of the Bronze Age: the Case of Syria. *In* Centre and Periphery in the Ancient World. Michael Rowlands, Mogens Larsen, and Kristian Kristiansen, eds. pp. 66-73. Cambridge: Cambridge University Press.
- Lombard, Pierre  
 1986 Iron Age Dilmun: A Reconsideration of City IV at Qala'at al-Bahrain. *In* Bahrain through the Ages the Archaeology. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 269-277. London: KPI Limited.
- 1999a Early Dilmun Burial Offerings. *In* Bahrain: The Civilisation of the Two Seas. Pierre Lombard, ed. pp. 56-71. Paris: Institut du Monde Arabe.
- 1999b The Occupation of Dilmun by the Kassites of Mesopotamia. *In* Bahrain: The Civilisation of the Two Seas, Pierre Lombard, ed. pp. 122-125. Paris: Institut du Monde Arabe.
- Longacre, William A.  
 1999 Standardization and Specialization: What's the Link? *In* Pottery and People: A Dynamic Interaction. James M. Skibo and Gary Feinman, eds. pp. 44-58. Salt Lake City: University of Utah Press.
- Mair, Victor H., ed.  
 2006 Contact and Exchange in the Ancient World: Perspectives on the Global Past. Honolulu: University of Hawaii Press.
- Malinowski, Bronislaw  
 1922 Argonauts of the Western Pacific: An Account of Native Enterprise and Adventure in the Archipelagoes of Melanesian New Guinea. Volume Studies in Economics and Political Science, no. 65. London: Routledge and Kegan Paul.
- Mallowan, Mel  
 1965 The Mechanics of Ancient Trade in Western Asia. *Iran* 3:1-7.
- Marfoe, Leon  
 1987 Cedar Forest to Sliver Mountain: Social Change and the Development of Long-distance Trade in Early Near Eastern Societies. *In* Centre and Periphery in the Ancient World. Michael Rowlands, Mogens Larsen, and Kristian Kristiansen, eds. pp. 25-35. Cambridge: Cambridge University Press.



- Matthews, Roger  
2003 *The Archaeology of Mesopotamia: Theories and Approaches*. New York: Routledge.
- Mauss, Marcel  
2000 *The Gift: The Form and Reason for Exchange in Archaic Societies*. W.D. Halls, transl. New York: W. W. Norton & Company.
- McCall, Gerald J. H.  
2002 A Summary of the Geology of the Iranian Makran. *Geological Society, London* 195:147-204.
- McIntosh, Jane  
2008 *The Ancient Indus Valley: New Perspectives*. Santa Barbara: ABC-CLIO.
- Meadow, Richard H., and Jonathan M. Kenoyer  
2005 Excavations at Harappa 2000-2001: New insights on Chronology and City Organization. In *South Asian Archaeology 2001*, C. Jarrige and V. Lefèvre, eds. pp. 207-224. Paris: Editions Recherche sur les Civilisations -ADPF.
- Melas, Manolis  
1991 Acculturation and Social Mobility in the Minoan World. *Aegeum* 7:169-188.
- Méry, Sophie  
1989 Studies of Bronze Age Pottery in the Oman Peninsula: an Archaeological Perspective. In *Oman Studies: Papers on the Archaeology and History of Oman*. Paulo M. Costa and Maurizio Tosi, eds. pp. 127-137. Roma: IsMEO.
- 1991a Origine et production des récipients de terre cuite dans la Péninsule d'Oman à l'âge du Bronze. *Paléorient* 17(2):51-78.
- 1991b Wadi Suq Fine Wares from Shimal and Hili Sites (United Arab Emirates): A Technological and Provenience Analysis. *Internationale Archaologie* (6):245-255.
- 1995 Archaeology of the Borderlands: 4th Millennium BC Mesopotamian Pottery at Ra's al-Hamra RH-5 (Sultanate of Oman). *Annali Istituto Universitario Orientale* 55:193-206.
- 2000 Les céramiques d'Oman et l'Asie moyenne: Une archéologie des échanges à l'Âge du Bronze. CNRS:169-189.
- 2007 Indian Pottery in Oman. In *The Shadow of the Ancestors: the Prehistoric Foundations of the Early Arabian Civilization in Oman*. Serge Cleuziou and Maurizio Tosi, eds. pp. 199-201. Oman: Ministry of Heritage and Culture.

Méry, Sophie, and Gerwulf Schneider

1996 Mesopotamian Wares in Eastern Arabia from 5th to 2nd Millennium BC: A Contribution of Archaeometry to the Reconstruction of Economical History. *Proceedings of the Seminar for Arabia Studies* 26:79-95.

2001 De l'Île de Dalma au Ra's al-Jinz: les Céramiques Mésopotamiennes dans la Péninsule d'Oman aux Ve-IIIe Millénaires. In *Etudes Mésopotamiennes. Recueil de Textes Offert à J.-L. Huot*. Catherine Breniquet and Christine Kempinski-Lecomte, eds. pp. 263-275. Paris: Bibliothèque de la Délégation Archéologique Française en Iraq 9.

Méry, Sophie, and M. James Blackman

1995 Black-jars of Meluhha: Production and Diffusion of an Indus Pottery Ware during the Second Half of the 3rd Millennium B.C. *Harappan Studies* 3:2-18.

1999 Harappa et Mohenjo-Daro: Deux Zones de Production de Jarres à Engobe Noir au Pakistan à la Période Indus. *Paléorient* 25(2):167-177.

Méry, Sophie, Carl Phillips, and Yves Calvet

1998 Dilmun Pottery in Mesopotamian and Magan from the End of the 3rd and Beginning of the 2nd Millennium B.C. In *Arabia and her Neighbours: Essays on Prehistorical and Historical Developments*. C.S. Phillips, Daniel T. Potts, and Sarah Searight, eds. pp. 133-148. Turnhout: Brepols.

Méry, Sophie, Roland Besenval, M. James Blackman, and Aurore Didier

2012 The Origin of the Third-millennium BC Fine Grey Wares Found in Eastern Arabia. In *Proceedings of the Seminar for Arabian Studies*. Janet Starkey, ed. pp. 195-204. London.

Milton, D. I.

1967 Geology of the Arabian Peninsula; Kuwait. In *Geological Survey Professional Paper* 560-F.

Mirti, P., Monica Gulmini, and M. Pace

2004 The Provenance of Red Figure Vases from Locri Epizephiri (Southern Italy): New Evidence by Chemical Analysis. *Archaeometry* 46:183-200.

Mitchell, T. C.

1986 Indus and Gulf Type Seals from Ur. In *Bahrain through the Ages the Archaeology*. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 269-277. London: KPI Limited.

Moon, Jane

2005 Pottery Vessels: Individual Examples. In *The Early Dilmun Settlement at Saar*. Robert Killick and Jane Moon, eds. pp. 279-291. Ludlow: Archaeological International.

- Mommsen, Hans, and Birgitta L. Sjöberg  
 2007 The Importance of the 'Best Relative Fit Factor' when Evaluating Elemental Concentration Data of Pottery Demonstrated with Mycenaean Sherds from Sinda, Cyprus. *Archaeometry* 49(2):359-371.
- Mughal, Mohammad R.  
 1992 Jhukar and the Late Harappan Cultural Mosaic of the Greater Indus Valley. *In* South Asian Archaeology. Catherine Jarrige, ed. pp. 213-221. Madison, Wisconsin: The Prehistory Press.
- Munita, C.S., R. P. Paiva, M. A. Alves, P. M. De Oliverira, and E. F. Momose  
 2001 Major and Trace Element Characterization of Prehistoric Ceramic from Rezende Archaeological Site. *Journal of Radioanalytical and Nuclear Chemistry* 248(1):93-96.
- Mynors, H.S.  
 1983 An Examination of Mesopotamian Ceramics Using Petrographic and Neutron Activation Analysis. *In* *Proceedings of the 22nd Symposium of Archaeometry*, A. Aspinall and E.S. Warren, eds. pp. 377-387. UK: University of Bradford.
- Neale, Walter C.  
 1957 Reciprocity and Redistribution in the Indian Village: Sequel to Some Notable Discussion. *In* Trade and Market in the Early Empires. Karl Polanyi, Conrad Arensberg, and Harry W. Pearson, eds. Illinois: The Free Press.  
 1962 *Economic Change in Rural India*. New Haven: Yale University Press.
- Negares, Hossein  
 2008 Mud volcanoes in Sistan and Baluchestan Provinces, Makran Coast, Southeast Iran. *Bulletin of the Geological Society of Malaysia* 54:1-7.
- Nielsen, Roger  
 Geochemical Earth Reference Model (GERM). Accessed February 22, 2011.  
<http://earthref.org/KDD/e:38/>
- Niziolek, Lisa C.  
 2011 Ceramic Production and Craft Specialization in the Prehistoric Philippines, A.D. 500 to 1600, Ph.D. dissertation, Department of Anthropology, University of Illinois.
- Nourel-Din, Safwat  
 1993 *The Stamp Seals of Failaka: An Aesthetic Analysis*. Kuwait: Kuwait National Museum.
- Oates, Joan  
 1986 The Gulf in Prehistory. *In* Bahrain Through the Ages the Archaeology. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 79-86. London: KPI Limited.

- Okun, Marcia L.  
1989 *The Early Roman Frontier in the Upper Rhine Area*. Oxford: British Archaeological Reports International Series 547.
- Olijdam, Eric  
1997 Babylonian Quest for LApis Lazuli and Dilmun during the City III Period. *In* South Asian Archaeology 1995, F.R. Allchin & B. Allchin, ed. pp. 119-126. New Delhi: Oxford and IBH.
- Oppenheim, Adolph L.  
1954 The Seafaring Merchants of Ur. *Journal of the American Oriental Society* 74:6-17.  
  
1964 *Ancient Mesopotamia, Portrait of a Dead Civilization*. Chicago: University of Chicago Press.
- Orlin, Louis L.  
1970 *Assyrian Colonies in Cappadocia*. Mouton: The Hague.
- Özgüç, Tahsin  
1950 Turk Tarih Kurumu Tarafandan Yapılan Kultepe Kazasa Raporu, 1948. Ankara: Turk Tarih Kurumu Basımevi.  
  
1953 Turk Tarih Kurumu Tarafandan Yapılan Kultepe Kazasa Raporu, 1949. Ankara: Turk Tarih Kurumu Basımevi  
  
1959 Kültepe-Kani: Asur Ticaret Kolonilerinin Merkezinde Yapılan Yeni Ara Tirmalar [The Palace and Temples of Kultepe-Kanis/Nesa]. Ankara: Turk Tarih Kurumu Basımevi.  
  
1999 Kültepe-Kani/Nesa sarayları ve mabetleri. Ankara: Türk Tarih Kurumu Basımevi.
- Papadopoulou, D.N., G.A. Zachariadis, A.N. Anthemidis, N.C. Tsirliganis, and J.A. Stratis  
2006 Development and Optimisation of a Portable microXRF Method for In Situ Multielement Analysis of Ancient Ceramics. *Talanta* 68(5):1692-1699.
- Papagrotgiou, I., and I. Liritzis  
2007 Multivariate Mixture of Normals with Unknown Number of Components: An Application to Cluster Neolithic Ceramics from the Aegean and Asia Minor. *Archaeometry* 49(4):795-813.
- Pauketat, Timothy R.  
2000 The Tragedy of the Commoners. *In* Agency and Archaeology, Marcia-Anne Dobres and John Robb, eds. pp. 111-129. London: Routledge.
- Peregrine, Peter N.  
1991 Some Political Aspects of Craft Specialization. *World Archaeology* 23:1-11.

- 1996 Introduction: World-Systems Theory and Archaeology. *In* Pre-Columbian World Systems. Peter N. Peregrine and Gary M. Feinman, eds. pp. 1-10. Madison: Prehistory Press.
- Peregrine, Peter N., and Gary M. Feinman, eds.  
1996 Pre-Columbian World Systems. Madison: Prehistory Press.
- Polanyi, Karl  
1957a Aristotle Discovers the Economy. *In* Trade and Market in the Early Empires. Karl Polanyi, Conrad Arensberg, and Harry W. Pearson, eds. pp. 64-94. Illinois: The Free Press.  
  
1957b The Economy as Instituted Process. *In* Trade and Market in the Early Empires. Karl Polanyi, Conrad Arensberg, and Harry W. Pearson, eds. pp. 243-270. Illinois: The Free Press.  
  
1957c Marketless Trading in Hummurabi's Time. *In* Trade and Market in the Early Empires. Karl Polanyi, Conrad Arensberg, and Harry W. Pearson, eds. pp. 12-26. Illinois: The Free Press.  
  
1963 Ports of Trade in Early Societies. *The Journal of Economic History* 23:30-45.
- Pollard, Mark  
1987 Report on the Analysis of Failaka Glass, Glazed Pottery and Faience. *In* The Bronze Age Pottery. Fleming Højlund, ed. pp. 185-189. Aarhus: JASP.
- Pollard, Mark, Catherine Batt, Ben Stern, and Suzanne Young  
2007 *Analytical Chemistry in Archaeology*. New York: Cambridge University Press.
- Pollock, Susan, Melody Pope, and Cheryl Coursey  
1996 Household Production at the Uruk Mound, Abu Salabikh, Iraq. *American Journal of Archaeology* 100(4):683-698.
- Potts, Daniel T.  
1990 The Arabian Gulf in Antiquity I.: From Prehistory to the Fall of the Achaemenid Empire. Oxford: Clarendon Press.
- Quinn, Patric  
2013 *Ceramic Petrography: The Interpretation of Archaeological Pottery & Related Artefacts in Thin Section*. Oxford: Archaeopress.
- Rajab, Jehan  
1999 *Failaka Island: The Ikaros of the Arabian Gulf*. Kuwait: Tareq Rajab Museum.

- Rao, S. R.  
1986 Trade and Cultural Contacts Between Bahrain and India in Third and Second Millennia B.C. *In Bahrain Through the Ages the Archaeology*. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 376-382. London: KPI Limited.
- Rapp, Georgia, and Christopher Hill  
2006 Geoarchaeology: The Earth-Science Approach to Archaeological Interpretation. 2nd ed. New Haven: Yale University Press.
- Ratnagar, Shireen  
2004 Trading Encounters, from the Euphrates to the Indus in the Bronze Age. NY: Delhi.
- Reade, Julian  
1986 Commerce or Conquest: Variation in the Mesopotamia-Dilmun Relationship. *In Bahrain Through the Ages the Archaeology*. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 269-277. London: KPI Limited.
- Redfield, Robert, Ralph Linton, and Melville Herskovits  
1936 Memorandum for the Study of Acculturation. *American Anthropologist* 38:149-152.
- Renfrew, Colin  
1969 Trade and Culture Process in European Prehistory. *Current Anthropology* 10:151-169.  
  
1972 *The Emergence of Civilization: Cyclades and the Aegean in the Third Millenium B.C.* London: Methuen.
- Renfrew, Colin, and John Cherry, eds.  
1986 *Peer Polity Interaction and Social-Political Change*. Cambridge: Cambridge University Press.
- Renfrew, Colin, and Paul Bahn  
2000 *Archaeology Theories Methods and Practice*. London: Thames and Hudson Publishing.
- Rice, Michael  
1994 *The Archaeology of the Arabian Gulf*. London: Routledge.
- Rice, Prudence. M.  
1991 Specialization, Standardization, and Diversity: A Retrospective. *In The Ceramic Legacy of Anna O. Shepard*. R.B.a.F. Lange, ed. Pp. 257-279. Niwot: University Press of Colorado.  
  
2005 *Pottery Analysis: A Source Book*. Chicago: The University of Chicago.

- Roseberry, William  
1989 *Anthropologies and Histories: Essays in Culture, History, and Political Economy*. New Jersey: Rutgers University Press.
- Rothman, Mitchell  
1994 Introduction Part 1. Evolutionary Typologies and Cultural Complexity. *In* Chiefdoms and Early States in the Near East: The Organizational Systematics of Complexity. Gil Stein and Mitchell Rothman, eds. pp. 1-10. Madison: Prehistory Press.
- Rotunno, T., L. Sabbatini, and M. Corrente  
1997 A Provenance Study of Pottery From Archaeological Sites Near Canosa, Puglia (Italy). *Archaeometry* 39:343-54.
- Rouse, Lynne M., and Lloyd R. Weeks  
2011 Specialization and Social Inequality in Bronze Age SE Arabia: Analyzing the Development of Production Strategies and Economic Networks using Agent-based Modeling. *Journal of Archaeological Science* 38:1583-1590.
- Sabloff, Jeremy, and C.C. Lamberg-Karlovsky, eds.  
1975 *Ancient Civilization and Trade*. Albuquerque: University of New Mexico Press.
- Sahlins, Marshall  
1972 *Stone Age Economics*. Chicago: Aldine.
- Santley, Robert S., Janet M. Kerley, and Ronald R. Kneebone  
1986 Obsidian Working, Long-Distance Exchange, and the Politico-economic Organization of Early States in Central Mexico. *In* Research in Economic Anthropology: A Research Annual: Economic Aspects of Prehispanic Highland Mexico. Barry L. Isaac, ed. pp. 101-132. Greenwich: JAI Press Inc.
- Scarre, Christopher, and Brian Fagan  
2008 *Ancient Civilizations*. New Jersey: Pearson Education.
- Schwartz, Glenn  
1994 Before Ebla: Models of Pre-State Political Organization in Syria and Northern Mesopotamia. *In* Chiefdoms and Early States in the Near East: The Organizational Systematics of Complexity. Gil Stein and Mitchell Rothman, eds. pp. 153-173. Madison: Prehistory Press.  
  
2001 Syria and the Uruk Expansion. *In* Uruk Mesopotamia and Its Neighbors: Cross-cultural Interactions in the Era of State Formation. Mitchell Rothman, ed. pp. 253-266. Santa Fe: SAR Press.
- Searle, Mike P., and John Malpas  
1980 The Structure and Metamorphism of Rocks Beneath the Semail Ophiolite of Oman and Their Significance in Ophiolite Obduction. *Earth Sciences* 71:247-262.

Service, Elman

1962 *Primitive Social Organization*. New York: Random House.

1975 *Origins of the State and Civilization: The Process of Cultural Evolution*. New York: W.W. Norton & Company.

Shackley, M. Steven

2005 *Obsidian: Geology and Archaeology in the North American Southwest*. Tucson: University of Arizona Press.

2011 An Introduction to X-Ray Fluorescence Analysis in Archaeology. In *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology*, M. Steven Shackley, ed. pp. 7-44. New York: Springer.

Shaw, Ian

2000 Egypt and the Outside World. In *The Oxford History of Ancient Egypt*. In *The Oxford History of Ancient Egypt*. Ian Shaw, ed. pp. 314-329. New York: Oxford University Press.

Shennan, Susan

1982 From Minimal to Moderate Ranking. In *Ranking, Resource and Exchange: Aspects of the Archaeology of Early European Society*. Colin Renfrew and Susan Shennan, eds. pp. 27-32. Cambridge: Cambridge University Press.

Sherratt, Andrew

1982 Mobile Resources, Settlement and Exchange in Early Agricultural Europe. In *Ranking, Resource and Exchange: Aspects of the Archaeology of Early European Society*. Colin Renfrew and Susan Shennan, eds. pp. 13-26. Cambridge: Cambridge University Press.

Sinopoli, Carla M.

1988 The Organization of Craft Production at Vijaynagara, South India. *American Anthropologist* 90(3):580-597.

1991 *Approaches to Archaeological Ceramics*. New York: Plenum Press.

2003 *Political Economy of Craft Production: Crafting Empire in South India, c. 1350-1650*. Cambridge: Cambridge University Press.

Smith, Dylan

2012 Handheld X-ray Fluorescence Analysis of Renaissance: Practical Approaches to Quantification and Acquisition. In *Studies in Archaeological Sciences: Handheld XRF for Art and Archaeology*. Aaron Shugar and Jennifer Mass, eds. Leuven: Leuven University Press.



So, Alvin Y.

1990 *Social Change and Development: Modernization, Dependency and World-System Theories*. Newbury Park: Sage Publications.

Speakman, Robert J., and Hector Neff

2005 The Application of Laser Ablation-ICP-MS to the Study of Archaeological Materials- An Introduction. *In* Laser Ablation-ICP-MS in Archaeological Research. Robert J. Speakman and Hector Neff, eds. pp. 1-16. USA: The University of New Mexico Press.

Speakman, Robert J., and M. Steven Schakley

2013 Silo Science and Portable XRF in Archaeology: A Response to Frahm. *Journal of Archaeological Science* 40(2):1435-1443.

Speakman, Robert, Nicole Little, Darrell Creel, Myles M Miller, and Javier Inanez

2011 Sourcing ceramics with portable XRF spectrometers? A comparison with INAA using Mimbres pottery from the American Southwest. *Journal of Archaeological Science* 38:3483-96.

Stein, Gil

1996 Producers, Patrons, and Prestige: Craft Specialists and Emergent Elites in Mesopotamia from 5500-3100 B.C. *In* Craft Specialization and Social Evolution: In Memory of V. Gordon Childe. Bernard Wailes, ed. pp. 25-38. Philadelphia: University Museum of Archaeology and Anthropology, University of Pennsylvania.

1998 Heterogeneity, Power, and Political Economy: Some Current Research Issue in the Archaeology of Old World Complex Society. *Journal of Archaeological Research* 6(1):1-27.

1999 *Rethinking World-System: Diasporas, Colonies, and Interaction in Uruk Mesopotamia*. Tucson: The University of Arizona Press.

2001 Indigenous Social Complexity at Hacinebi (Turkey) and the Organization of Colonial Contact in the Uruk Expansion. *In* Uruk Mesopotamia and its Neighbors: Cross-cultural Interactions in the Era of State Formation. Mitchell Rothman, ed. pp. 265-305. Santa Fe: SAR Press.

2002 From Passive Periphery to Active Agents: Emerging Perspectives in the Archaeology of Interregional Interaction. *American Anthropologist* 104(3):903-916.

Stein, Gil, and M. James Blackman

1993 The Organizational Context of Specialized Craft Production in Early Mesopotamian States. *Research in Economic Anthropology* 14:29-59.

- Stein, Gil, and Mitchell Rothman  
1994 *Chiefdoms and Early States in the Near East: The Organizational Dynamics of Complexity*. Volume Monographs in World Prehistory 18. Madison: Prehistory Press.
- Steve, Marie-Joseph, and Henri Gasche  
1971 *L'Acropole de Suse: nouvelles fouilles (Rapport préliminaire)*. Mémoires de la Délégation Archéologique en Iran, XLVI. Paris: Geuthner.
- Stiebing, William  
1993 *Uncovering The Past: A History of Archaeology*. USA: Oxford University Press.
- Stiffe, Arthur W.  
1897 Ancient Trading Centers of the Persian Gulf, III: Pre-Mohammedan Settlements. *Geographical Journal* 9(3):309-314.
- Stremtan, Ciprian, Hasan Ashkanani, Robert H. Tykot, and Montana Puscas  
2014 Constructing a Database for pXRF, XRD, ICP-MS and Petrographic Analyses of Bronze Age Ceramics and Raw Materials from Failaka Island (Kuwait). In *Proceedings of the 39th International Symposium for Archaeometry*, Leuven (2012). Rebecca B. Scott, Mike Carremans and Patrick Degryse, eds. pp. 274-279. Leuven: Centre for Archaeological Sciences.
- Sumner, William  
1994 The Evolution of Tribal Society in the Southern Zagros Mountain, Iran. In *Chiefdoms and Early States in the Near East: The Organizational Dynamics of Complexity*. Gil Stein and Mitchell Rothman, eds. pp. 47-66. Madison: Prehistory Press.
- Thareani, Yifat  
2009 The Spirit of Clay: "Edomite Pottery" and Social Awareness in the Late Iron Age. *BASOR* 359:35-55.
- Tite, Micahel S.  
1972 *Methods of Physical Examination in Archaeology*. London: Seminar Press.  
  
1999 Pottery production, Distribution, and Consumption: The Contribution of the Physical Sciences. *Journal of Archaeological Method and Theory* 6(3):181-233.
- Trigger, Bruce  
1989 *A History of Archaeological Thought*. London: Cambridge University Press.
- Tykot, Robert H.  
2002 Chemical Fingerprinting and Source Tracing of Obsidian: The Central Mediterranean Trade in Black Gold. *Accounts of Chemical Research* 35:618-627.

- 2003 Determining the Source of Lithic Artifacts and Reconstructing Trade in the Ancient World. *In* Written in Stone: The Multiple Dimensions of Lithic Analysis. P. Nick Kardulias and Richard Yerkes, eds. pp. 59-85. Lanham: Lexington Books.
- Tykot, Robert H., L. Lai, and C. Tozzi  
2011 Intra-Site Obsidian Subsource Patterns at Contraguda, Sardinia (Italy),. *In* Proceedings of the 37th International Symposium on Archaeometry, 13th-16th May 2008, Siena, Italy. Isabella Turbanti-Memmi, ed. pp. 321-328. Berlin: Springer.
- Tykot, Robert H., Teddi Setzer, Michael D. Glascock, and Robert J. Speakman  
2005 Identification and Characterization of the Obsidian Sources on the Island of Palmarola, Italy. *Geoarchaeological and Bioarchaeological Studies* 3(107-111).
- Tykot, Robert H., N. M. White, J. P. DuVernay, J. S. Freeman, C. T. Hays, M. Koppe, C. N. Hunt, R. A. Wienstien, and D. S. Woodward  
2013 Advantages and Disadvantages of pXRF for Archaeological Ceramic Analysis: Prehistoric Pottery Distribution and Trade in NW Florida. *In* Archaeological Chemistry VIII. Ruth A. Armitage and James H. Burton, eds. pp. 245-267. Washington, DC: American Chemical Society.
- UN-ESCWA, and BGR  
2013 Inventory of Shared Water Resources in Western Asia (Report). Beirut.
- Underhill, Anne P.  
2003 Investigating Variation in Organization of Ceramic Production: An Ethnoarchaeological Study in Guizhou, China. *Journal of Archaeological Method and Theory* 10(3):203-275.
- Urban, Patricia A., and Edward M. Schortman  
1999 Thoughts on the Periphery: The Ideological Consequences of Core/Periphery Relations. *In* World-Systems Theory in Practice: Leadership, Production, and Exchange, P. Nick Kardulias, ed. pp. 125-152. Lanham: Rowman and Littlefield Publishers.
- Van der Leeuw, Sander  
1977 Towards a Study of the Economics of Pottery Making. *In* Ex Horreo, Cingvla 4. B. L. Beek, R.W. Brant, and W. Gruenman van Watteringe, eds. pp. 68-76. . Amsterdam: Albert Egges van Giffen Instituut voor Prae- en Protohistorie, University of Amsterdam.
- Veenhof, Klaas R.  
1972 *Aspects of old Assyrian Trade and its Terminology*. Leiden: Brill.
- Vidale, Massimo  
1989 Specialized Producers and Urban Elites: On the Role of Craft Industries in Mature Harappan Urban Contexts. *In* Old Problems and New Perspectives in the Archaeology of South Asia. Jonathan M. Kenoyer, ed. pp. 171-181. Madison: University of Wisconsin.

- Vine, Peter  
1993 *Bahrain National Museum*. London: Immel Publishing Ltd.
- Wallerstein, Immanuel  
1974 *The Modern World System*. San Diego: Academic Press.
- Weisgerber, Gerd  
1986 Dilmun-A Trading Entrepôt: Evidence from Historical and Archaeological Sources. In *Bahrain through the Ages the Archaeology*. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 135-142. London: KPI Limited.
- Wells, E. Christian  
2012 Crafting and Manufacturing in Mesoamerica: Critical Engagements with Theory and Method. In *The Oxford Handbook of Mesoamerican Archaeology*. Deborah L. Nichols and Christopher A. Pool, eds. pp. 588-598. USA: Oxford University Press.
- Whitecotton, Joseph, and Richard Pailles  
1986 Aspects of old Assyrian Trade and its Terminology. In *Ripples in the Chichimec Sea*. Frances J. Mathien and Randall H. McGuire, eds. pp. 181-204. Carbondale: Southern Illinois University Press.
- Williams, Rick  
2003 Terminology Used in Instrument Accuracy. *Proceedings American School of Gas Measurement Technology* pp. 279-284.
- Willis, Ronald P.  
1967 *Geology of the Arabian Peninsula Bahrain*. Geological Survey Professional Paper 560-E. United States Government Printing Office, Washington.
- Wright, Henry  
1977 Recent Research on the Origin of the State. *Annual Review of Anthropology* 6:379-397.  
  
1978 Toward an Explanation of the Origin of the State. In *Origins of the State: The Anthropology of Political Evolution*. Ronald Cohen and Elman Service, eds. pp. 49-68. Philadelphia: Institute for the Study of Human Issues.  
  
1981 *An Early Town on the Deh Luran Plain, Excavations at Tepe Farukhabad*. Ann Arbor: University of Michigan Museum of Anthropology.  
  
2010 Early Historic Settlement Patterns on the Deh Luran Plain. In *Elamite and Achaemenid Settlement on the Deh Luran Plain; Towns and Villages of the Early Empires in Southwestern Iran*, Henry Wright and James A. Neely, eds. Ann Arbor: University of Michigan Museum of Anthropology.

- Wright, Henry, and Gregory Johnson  
 1975 Population, Exchange, and Early State Formation in Southwestern Iran. *American Anthropologist* 77:267-289.
- Wright, Henry, and James A. Neely, eds.  
 2010 *Elamite and Achaemenid Settlement on the Deh Luran Plain; Towns and Villages of the Early Empires in Southwestern Iran*. Ann Arbor: University of Michigan Museum of Anthropology.
- Wright, Rita  
 1984 Technology, Style, and Craft Specilization: Spheres of Interaction and Exchange in the Indo-Iranian Borderlands, Third Millennium B.C. Dissertation, The Department of Anthropology, Harvard University.
- 1998 Crafting Social Identity in Ur III Southern Mesopotamia. In *Craft and Social Identity*. Cathy L.Costin and Rita R.Wright, eds. pp. 57-69. Arlington: American Anthropological Association.
- Yerkes, Richard W.  
 1983 Microwear, Microdrills, and Mississippian Craft Specialization. *American Antiquity* 48(3):499-518.
- Yoffee, Norman  
 1979 The Decline and Rise of Mesopotamian Civilization: An Ethnoarchaeological Perspective on the Evolution of Social Complexity. *American Antiquity* 44:5-35.
- Zarins, Juris  
 1986 MAR-TU and the Land of Dilmun. In *Bahrain Through the Ages the Archaeology*. Shaikha Haya Al Khalifa and Michael Rice, eds. pp. 389-398. London: KPI Limited.

## APPENDIX A: A LIST OF ABBREVIATIONS USED IN DISSERTATION

pXRF	Portable X-ray Fluorescence
AAS	Atomic Absorption Spectrometry
ICP	Inductively Coupled Plasma
INAA (NAA)	Instrumental Neutron Activation Analysis
LA-ICP-MS	Laser Ablation Inductively Coupled Plasma Mass Spectrometry
XRD	X-ray Diffraction
PIXE	Proton-induced X-ray emission
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
SEM	Scanning Electron Microscope
PCA	Principal Component Analysis
DFA	Discriminant Function Analysis

**APPENDIX B: LIST OF ELEMENTAL COMPOSITIONS (AS DETERMINED BY  
PXRF) OF THE ANALYZED 304 SAMPLES. VALUES ARE IN PPM.**

<b>No.</b>	<b>USF No.</b>	<b>Site</b>	<b>Region</b>	<b>Ba</b>	<b>Th</b>	<b>Rb</b>	<b>Sr</b>	<b>Y</b>	<b>Zr</b>	<b>Nb</b>
1	13608	F6 The Palace	Kuwait	1765	5	78	742	29	117	45
2	13609	F6 The Palace	Kuwait	1798	5	72	645	27	99	43
3	13610	F6 The Palace	Kuwait	1865	4	54	772	27	145	43
4	13611	F6 The Palace	Kuwait	1741	4	58	542	28	126	45
5	13612	F6 The Palace	Kuwait	1524	6	82	468	32	149	48
6	13613	F6 The Palace	Kuwait	4975	5	51	409	34	129	47
7	13614	F6 The Palace	Kuwait	1882	5	77	517	30	113	47
8	13615	F6 The Palace	Kuwait	1786	4	65	641	27	142	45
9	13616	F6 The Palace	Kuwait	2769	2	59	1049	26	163	42
10	13617	F6 The Palace	Kuwait	1670	6	70	376	30	141	48
11	13618	F6 The Palace	Kuwait	4124	6	61	398	32	177	48
12	13619	F6 The Palace	Kuwait	1817	6	62	636	27	137	45
13	13620	F6 The Palace	Kuwait	6418	9	67	472	34	193	52
14	13621	F6 The Palace	Kuwait	1917	4	61	838	25	121	43
15	13622	F6 The Palace	Kuwait	1955	4	79	848	28	130	42
16	13623	F6 The Palace	Kuwait	1588	5	77	368	29	141	46
17	13625	F3 Period 2	Kuwait	2032	6	85	633	28	114	45
18	13626	F3 Period 2	Kuwait	2182	3	47	922	27	137	44
19	13627	F3 Period 2	Kuwait	2406	5	68	1197	27	142	42
20	13628	F3 Period 2	Kuwait	2058	6	84	688	28	128	46
21	13629	F3 Period 2	Kuwait	1743	6	70	446	29	152	51
22	13631	F3 Period 2	Kuwait	2576	4	43	1261	26	128	42
23	13632	F3 Period 2	Kuwait	1825	6	85	561	29	117	48
24	13633	F3 Period 2	Kuwait	1800	5	72	513	31	107	44
25	13634	F3 Period 2	Kuwait	1756	6	79	483	30	112	47
26	13635	F3 Period 2	Kuwait	2735	5	49	1551	26	120	37
27	13636	F3 Period 2	Kuwait	2199	6	78	685	30	178	49
28	13637	F3 Period 3A	Kuwait	3104	5	33	1673	30	142	43
29	13641	F3 Period 3A	Kuwait	2678	3	56	1594	26	134	40
30	13642	F3 Period 3A	Kuwait	2948	3	68	1629	28	176	45
31	13644	F3 Period 3A	Kuwait	2879	3	59	1787	25	133	41

32	13645	F3 Period 3A	Kuwait	2151	4	63	823	28	134	45
33	13646	F3 Period 3A	Kuwait	2147	4	30	770	30	116	45
34	13647	F3 Period 3B	Kuwait	2825	5	74	1386	27	118	38
35	13648	F3 Period 3B	Kuwait	4093	2	39	4000	21	125	21
36	13649	F3 Period 3B	Kuwait	2961	5	77	1235	26	167	45
37	13650	F3 Period 3B	Kuwait	3049	4	33	2033	25	115	36
38	13651	F3 Period 3B	Kuwait	3356	4	78	2555	21	140	33
39	13652	F3 Period 3B	Kuwait	3982	5	61	2825	21	155	36
40	13653	F3 Period 3B	Kuwait	2947	6	69	2478	24	163	40
41	13654	F3 Period 3B	Kuwait	3160	6	85	1921	24	128	37
42	13655	F3 Period 3B	Kuwait	3370	6	70	2007	25	166	39
43	13656	F3 Period 3B	Kuwait	3931	4	39	3798	22	130	27
44	13657	F3 Period 3B	Kuwait	2311	6	66	1022	27	159	45
45	13658	F3 Period 3B	Kuwait	3654	4	48	3098	23	176	40
46	13659	Barbar Temple llb	Bahrain	1750	10	143	741	24	159	48
47	13660	Barbar Temple llb	Bahrain	1611	7	73	445	29	156	48
48	13661	Barbar Temple llb	Bahrain	1856	4	26	672	31	103	46
49	13662	Barbar Temple llb	Bahrain	2126	4	37	973	28	120	43
50	13663	Barbar Temple llb	Bahrain	2265	4	66	852	26	124	43
51	13664	Barbar Temple llb	Bahrain	2108	7	79	423	31	154	49
52	13665	Barbar Temple llb	Bahrain	1941	5	77	661	29	134	47
53	13666	Barbar Temple llb	Bahrain	1522	5	76	580	28	101	44
54	13667	Barbar Temple llb	Bahrain	1688	6	61	419	30	141	50
55	13668	Barbar Temple llb	Bahrain	2218	4	52	1087	24	114	40
56	13669	NE Temple ARP	Bahrain	1626	4	58	515	29	156	46
57	13670	NE Temple ARP	Bahrain	1886	4	44	617	29	131	47
58	13671	NE Temple ARP	Bahrain	1847	3	31	573	30	137	48
59	13672	NE Temple ARP	Bahrain	1810	4	51	636	30	139	46
60	13673	NE Temple ARP	Bahrain	1970	5	59	872	29	138	46
61	13674	NE Temple ARP	Bahrain	1639	6	67	424	29	154	47
62	13675	NE Temple ARP	Bahrain	1659	4	45	611	29	135	43
63	13676	NE Temple ARU	Bahrain	1430	4	60	384	28	138	47
64	13677	NE Temple	Bahrain	1401	6	78	255	30	135	47



		ARU								
65	13678	NE Temple ARU	Bahrain	1376	6	76	360	31	125	47
66	13679	NE Temple ARU	Bahrain	1550	5	63	355	30	112	47
67	13680	Qala'at Period IIF	Bahrain	1716	5	63	658	26	119	43
68	13681	Qala'at Period IIF	Bahrain	2545	3	59	1481	26	124	40
69	13682	Qala'at Period IIF	Bahrain	1746	3	63	470	28	134	48
70	13683	Qala'at Period IIF	Bahrain	1983	4	51	764	28	123	44
71	13684	Qala'at Period IIF	Bahrain	1893	8	57	828	26	139	43
72	13685	Qala'at Period IIF	Bahrain	1849	6	74	576	29	151	50
73	13686	Qala'at Period IIF	Bahrain	2689	5	54	1378	27	160	42
74	13687	Qala'at Period IIF	Bahrain	1911	5	53	806	27	139	43
75	13688	Qala'at Period IIF	Bahrain	1345	6	65	319	26	106	46
76	13689	Qala'at Period IIIa	Bahrain	1676	4	43	627	27	116	45
77	13690	Qala'at Period IIIa	Bahrain	2156	3	56	1094	26	114	42
78	13691	Qala'at Period IIIa	Bahrain	1877	3	32	800	26	111	45
79	13692	Qala'at Period IIIa	Bahrain	1678	6	59	600	27	119	45
80	13693	Qala'at Period IIIa	Bahrain	2974	5	40	1534	15	144	40
81	13694	Al-Khidr	Kuwait	1265	10	109	401	27	149	51
82	13695	Al-Khidr	Kuwait	1603	4	9	353	30	91	48
83	13696	Al-Khidr	Kuwait	1987	4	45	432	28	135	47
84	13697	Al-Khidr	Kuwait	2144	6	57	438	27	142	49
85	13698	Al-Khidr	Kuwait	1696	6	53	466	29	91	45
86	13699	Al-Khidr	Kuwait	2296	5	39	1209	25	128	41
87	13700	Al-Khidr	Kuwait	1768	4	59	724	28	140	43
88	13701	Al-Khidr	Kuwait	1949	5	63	667	28	140	46
89	14224	Al-Khidr	Kuwait	2162	5	42	736	29	144	44
90	14225	Al-Khidr	Kuwait	2514	5	24	647	34	124	49
91	14226	Al-Khidr	Kuwait	2794	7	77	734	29	166	46
92	14227	Al-Khidr	Kuwait	2440	7	94	685	31	171	51
93	14228	Al-Khidr	Kuwait	1841	8	94	491	32	148	48
94	14229	Al-Khidr	Kuwait	2172	8	60	606	34	131	49
95	14230	Al-Khidr	Kuwait	2819	6	84	644	29	157	47
96	14231	Al-Khidr	Kuwait	2535	4	28	876	32	153	45
97	14232	Al-Khidr	Kuwait	2316	9	79	423	31	166	53

98	14233	Al-Khidr	Kuwait	2575	6	36	609	31	131	48
99	14234	Al-Khidr	Kuwait	3025	8	99	508	29	179	52
100	14235	Al-Khidr	Kuwait	2953	5	52	1473	25	154	41
101	14236	Al-Khidr	Kuwait	8893	8	60	535	33	147	47
102	14237	Al-Khidr	Kuwait	2593	7	85	812	28	153	46
103	14238	Al-Khidr	Kuwait	2505	6	99	542	32	187	52
104	14239	Al-Khidr	Kuwait	2616	5	77	967	28	117	41
105	14240	Al-Khidr	Kuwait	1841	5	74	768	29	170	48
106	14241	Al-Khidr	Kuwait	2874	10	99	674	32	152	48
107	14242	Al-Khidr	Kuwait	2494	6	46	908	28	149	45
108	14243	Al-Khidr	Kuwait	2693	6	67	899	29	178	47
109	14244	Al-Khidr	Kuwait	2576	4	73	859	24	158	46
110	14245	Al-Khidr	Kuwait	2559	6	71	952	26	127	43
111	14246	Al-Khidr	Kuwait	2500	4	39	840	29	159	47
112	14247	Al-Khidr	Kuwait	2358	9	89	633	28	172	50
113	14248	Al-Khidr	Kuwait	2308	5	43	904	29	156	48
114	14249	Al-Khidr	Kuwait	2473	8	97	456	31	131	48
115	14250	Al-Khidr	Kuwait	2113	8	100	477	32	183	52
116	14251	Al-Khidr	Kuwait	2211	6	75	613	26	136	46
117	14252	Al-Khidr	Kuwait	2312	6	52	692	29	151	47
118	14253	Al-Khidr	Kuwait	2098	8	88	477	30	155	51
119	14254	Al-Khidr	Kuwait	2599	6	72	859	27	142	44
120	14255	Al-Khidr	Kuwait	1858	7	73	540	29	141	47
121	14256	Al-Khidr	Kuwait	2473	6	101	1004	29	141	44
122	14257	Al-Khidr	Kuwait	2652	7	95	694	28	168	47
123	14258	Al-Khidr	Kuwait	1654	10	153	294	27	164	52
124	14259	Al-Khidr	Kuwait	7853	6	62	755	31	136	45
125	14260	Al-Khidr	Kuwait	2896	9	90	420	31	185	51
126	14261	Al-Khidr	Kuwait	2339	8	86	533	34	174	52
127	14262	Al-Khidr	Kuwait	2367	6	73	772	27	155	47
128	14263	Al-Khidr	Kuwait	3067	8	76	713	31	163	47
129	14264	Al-Khidr	Kuwait	3546	6	65	1211	29	140	45
130	14265	Al-Khidr	Kuwait	2250	6	99	714	28	134	47
131	14266	Al-Khidr	Kuwait	2074	5	40	712	27	137	45
132	14267	Al-Khidr	Kuwait	3128	6	78	1042	28	163	46
133	14268	Al-Khidr	Kuwait	2829	6	66	783	31	167	48
134	14269	Al-Khidr	Kuwait	2427	8	65	840	30	160	49
135	14270	Al-Khidr	Kuwait	4144	9	70	1345	31	202	50
136	14271	Al-Khidr	Kuwait	2190	3	65	851	26	126	44
137	14273	Al-Khidr	Kuwait	2192	6	60	974	28	180	42
138	14274	Al-Khidr	Kuwait	2316	6	50	803	28	147	48
139	14275	Al-Khidr	Kuwait	1770	6	60	562	28	134	46

140	14277	Al-Khidr	Kuwait	2539	6	76	858	28	153	46
141	14278	Al-Khidr	Kuwait	2041	6	61	391	30	161	51
142	14279	Al-Khidr	Kuwait	2400	5	45	1056	28	138	43
143	14280	Al-Khidr	Kuwait	2242	6	24	911	31	105	45
144	14281	Al-Khidr	Kuwait	3402	3	57	1767	26	163	40
145	14282	Al-Khidr	Kuwait	3062	7	95	419	32	145	48
146	14283	Al-Khidr	Kuwait	3454	8	65	654	33	180	51
147	14284	Al-Khidr	Kuwait	2802	7	20	548	34	113	48
148	14285	Al-Khidr	Kuwait	2872	7	72	1036	23	136	44
149	14286	Al-Khidr	Kuwait	2729	8	99	604	27	174	46
150	14287	Al-Khidr	Kuwait	2886	6	86	851	29	168	49
151	14288	Al-Khidr	Kuwait	3061	7	83	741	30	172	48
152	14289	Al-Khidr	Kuwait	2586	7	82	677	16	153	47
153	14290	Al-Khidr	Kuwait	3059	7	80	841	26	138	43
154	14291	Al-Khidr	Kuwait	2673	7	63	929	27	143	45
155	14292	Al-Khidr	Kuwait	2762	7	75	760	27	155	47
156	14293	Al-Khidr	Kuwait	2342	5	46	938	17	97	46
157	14294	Al-Khidr	Kuwait	2357	6	71	884	28	158	46
158	14295	Al-Khidr	Kuwait	2411	6	54	1045	28	161	47
159	14296	Al-Khidr	Kuwait	2544	5	76	859	28	154	46
160	14297	Al-Khidr	Kuwait	2229	5	25	583	32	119	47
161	14298	Al-Khidr	Kuwait	2228	5	53	808	28	170	47
162	14299	Al-Khidr	Kuwait	2543	7	68	693	29	141	48
163	14300	Al-Khidr	Kuwait	1879	5	77	662	28	146	46
164	14301	Al-Khidr	Kuwait	2034	8	74	753	30	134	44
165	14302	Al-Khidr	Kuwait	2374	8	93	766	29	157	49
166	14303	Al-Khidr	Kuwait	2746	7	72	701	29	177	50
167	14304	Al-Khidr	Kuwait	2302	4	42	1011	29	150	44
168	14305	Al-Khidr	Kuwait	2318	7	66	590	29	146	48
169	14306	Al-Khidr	Kuwait	2571	5	58	1289	25	126	41
170	14307	Al-Khidr	Kuwait	2630	7	44	945	30	135	46
171	14308	Al-Khidr	Kuwait	4907	10	77	870	22	219	59
172	15119	F6 _ Trench E	Kuwait	2372	8	92	542	32	122	49
173	15120	F6 _ Trench E	Kuwait	2979	7	92	813	31	150	47
174	15121	F6 _ Trench E	Kuwait	2755	9	102	785	29	136	46
175	15122	F6 _ Trench E	Kuwait	2566	6	80	589	33	122	46
176	15123	F6 _ Trench E	Kuwait	2826	9	100	797	30	133	48
177	15124	F6 _ Trench E	Kuwait	2428	8	76	468	31	167	49
178	15125	F6 _ Trench E	Kuwait	2624	6	93	685	29	163	48
179	15126	F6 _ Trench E	Kuwait	2673	7	80	527	30	118	48
180	15127	F6 _ Trench E	Kuwait	2722	6	77	1027	28	121	43
181	15128	F6 _ Trench E	Kuwait	2455	8	84	513	29	167	48

182	15129	F6 _ Trench E	Kuwait	3274	9	92	513	33	133	49
183	15130	F6 _ Trench E	Kuwait	2434	7	86	597	31	124	47
184	15131	F6 _ Trench E	Kuwait	3081	6	91	867	32	151	47
185	15132	F6 _ Trench E	Kuwait	3621	8	88	627	29	169	49
186	15133	F6 _ Trench E	Kuwait	3101	8	96	835	28	135	48
187	15134	F6 _ Trench E	Kuwait	2814	7	114	841	26	133	47
188	15135	F6 _ Trench E	Kuwait	2299	8	88	388	31	112	50
189	15136	F6 _ Trench E	Kuwait	2601	7	75	420	34	163	51
190	15137	F6 _ Trench E	Kuwait	1710	6	22	590	31	92	45
191	15138	F6 _ Trench E	Kuwait	2617	12	131	258	31	147	52
192	15139	F6 _ Trench E	Kuwait	10892	7	67	720	30	170	49
193	15140	F6 _ Trench E	Kuwait	2968	8	89	878	29	135	44
194	15141	F6 _ Trench E	Kuwait	3334	9	104	389	34	153	52
195	15142	F6 _ Trench E	Kuwait	3212	6	89	980	30	153	46
196	15143	F6 _ Trench E	Kuwait	3018	8	97	525	35	146	50
197	15144	F6 _ Trench E	Kuwait	3765	7	86	688	31	152	47
198	15145	F6 _ Trench E	Kuwait	3115	9	99	456	33	154	51
199	15146	F6 _ Trench E	Kuwait	3098	8	92	475	34	161	50
200	15147	F6 _ Trench E	Kuwait	2499	7	99	345	33	132	51
201	15148	F6 _ Trench E	Kuwait	2471	6	79	463	32	128	47
202	15149	F6 _ Trench E	Kuwait	1975	4	80	523	26	140	48
203	15150	F6 _ Trench E	Kuwait	2893	8	84	534	31	127	49
204	15151	F6 _ Trench E	Kuwait	3606	8	90	872	29	140	44
205	15152	F6 _ Trench E	Kuwait	3128	9	86	567	32	131	47
206	15153	F6 _ Trench E	Kuwait	2705	8	80	383	20	126	50
207	15154	F6 Meso. House	Kuwait	2657	5	28	433	35	111	49
208	15155	F6 Meso. House	Kuwait	2529	6	46	370	33	127	48
209	15156	F6 Meso. House	Kuwait	2289	6	49	308	32	108	48
210	15157	F6 Meso. House	Kuwait	2056	5	28	760	31	124	49
211	15158	F6 Meso. House	Kuwait	3478	6	43	720	32	123	44
212	15159	F6 Meso. House	Kuwait	2303	5	28	452	33	142	47
213	15160	F6 Meso. House	Kuwait	2459	6	23	757	34	104	47
214	15161	F6 Meso. House	Kuwait	2878	6	26	469	34	117	50
215	15162	F6 Meso. House	Kuwait	2765	5	18	315	37	123	50
216	15163	F6 Meso. House	Kuwait	2625	6	81	763	30	119	48
217	15164	F6 Meso. House	Kuwait	2389	5	20	678	30	102	45

218	15165	F6 Meso. House	Kuwait	2491	6	25	508	34	130	50
219	15166	F6 Meso. House	Kuwait	2709	5	20	449	34	119	49
220	15167	F6 Meso. House	Kuwait	2824	5	46	779	31	112	46
221	15168	F6 Meso. House	Kuwait	2486	5	26	519	36	110	49
222	15170	F6 Meso. House	Kuwait	3681	4	34	2299	26	141	39
223	15171	F6 Meso. House	Kuwait	2501	4	18	629	32	99	46
224	15172	F6 Meso. House	Kuwait	3239	4	46	2300	24	122	40
225	15538	Tepe Farukhabad	Iran	1981	3	22	756	17	96	43
226	15539	Tepe Farukhabad	Iran	2883	7	67	1357	27	105	42
227	15540	Tepe Farukhabad	Iran	2155	3	46	1119	28	100	42
228	15541	Tepe Farukhabad	Iran	2444	4	39	1316	28	104	37
229	15542	Tepe Farukhabad	Iran	3420	4	50	2333	26	142	40
230	15543	Susiana Plain	Iran	2656	8	64	714	29	114	52
231	15544	Susiana Plain	Iran	2547	5	46	747	29	99	50
232	15545	Susiana Plain	Iran	2770	4	21	939	30	108	47
233	15546	Susiana Plain	Iran	2484	5	27	919	29	94	46
234	15547	Susiana Plain	Iran	2779	6	26	1193	30	106	47
235	15548	Susiana Plain	Iran	2753	6	38	768	30	119	50
236	15549	Susiana Plain	Iran	2540	6	30	983	29	96	46
237	15550	Susiana Plain	Iran	2500	5	47	955	31	98	49
238	15551	Susiana Plain	Iran	2747	6	41	665	33	119	50
239	15552	Susiana Plain	Iran	2487	7	57	810	26	88	48
240	15553	Susiana Plain	Iran	2673	8	59	864	28	123	44
241	15554	Susiana Plain	Iran	2834	6	53	896	29	99	46
242	15555	Susiana Plain	Iran	3181	3	35	1324	31	111	45
243	15556	Susiana Plain	Iran	2361	4	47	661	30	101	45
244	15557	Susiana Plain	Iran	2653	5	58	851	29	121	47
245	15558	Susiana Plain	Iran	2859	3	36	1043	29	126	43
246	15559	Susiana Plain	Iran	3493	6	43	1226	29	133	47
247	15560	Susiana Plain	Iran	2928	5	28	763	30	120	46
248	15561	Susiana Plain	Iran	3810	5	49	2470	25	131	41
249	15562	Susiana Plain	Iran	2798	5	59	1026	28	104	43
250	15563	Susiana Plain	Iran	2692	5	46	1057	29	114	42
251	15564	Susiana Plain	Iran	2616	5	23	683	32	113	48
252	15565	Susiana Plain	Iran	2254	5	27	697	31	103	49
253	15566	Susiana Plain	Iran	2893	5	22	678	32	115	50

254	15567	N. Susiana	Iran	4245	4	40	2553	25	131	42
255	15568	N. Susiana	Iran	6354	3	47	7601	2	219	40
256	15570	N. Susiana	Iran	3306	6	64	1321	15	122	44
257	15571	N. Susiana	Iran	4305	5	42	2232	27	143	43
258	15572	N. Susiana	Iran	4069	6	58	1241	28	135	43
259	15573	N. Susiana	Iran	2997	7	70	862	28	116	47
260	15574	N. Susiana	Iran	3088	9	81	888	21	170	50
261	15575	Clay	Kuwait	2277	9	95	451	23	134	51
262	15576	Clay	Bahrain	1124	4	33	205	13	51	45
263	15577	Clay	Bahrain	1127	4	39	243	13	68	44
264	15578	Clay	KSA	1743	7	76	115	24	153	53
265	15579	Clay	KSA	1054	5	60	111	20	115	50
266	15580	Clay	KSA	1367	6	47	292	19	151	47
267	15581	Clay	KSA	1391	5	114	189	10	98	47
268	15582	Clay	KSA	1409	7	115	188	13	102	48
269	15583	Clay	Kuwait	997	6	58	145	14	182	46
270	15584	Clay	Kuwait	3415	1	43	2691	8	71	43
271	15586	Clay	Kuwait	3829	3	48	3524	6	122	40
272	15626	Mound E	Pakistan	1034	18	161	121	39	180	54
273	15627	Mound E	Pakistan	856	17	148	92	41	156	54
274	15628	Mound E	Pakistan	1424	14	162	143	43	174	56
275	15629	Mound E	Pakistan	987	12	144	137	38	158	53
276	15630	Mound E	Pakistan	1291	14	162	136	39	164	55
277	15631	Mound E	Pakistan	979	13	176	84	40	158	54
278	15632	Mound E	Pakistan	1222	15	167	130	37	165	55
279	15633	Mound E	Pakistan	1137	14	163	180	37	181	53
280	15634	Mound E	Pakistan	1465	15	162	120	41	154	54
281	15635	Mound E	Pakistan	1136	15	167	170	38	169	53
282	15636	Mound E	Pakistan	826	20	177	90	40	170	53
283	15637	Mound E	Pakistan	993	17	176	72	41	156	56
284	15638	Mound E	Pakistan	1094	17	166	126	44	163	54
285	15639	Mound E	Pakistan	1172	18	168	129	33	161	53
286	15640	Mound E	Pakistan	1106	19	180	129	39	159	55
287	15641	Mound E	Pakistan	996	16	160	127	41	169	53
288	15642	Mound E	Pakistan	1109	14	163	79	39	149	54
289	15643	Mound E	Pakistan	1211	18	194	110	39	162	56
290	15644	Mound E	Pakistan	1063	15	179	93	39	148	56
291	15645	Mound E	Pakistan	1034	15	164	119	26	160	53
292	15646	Mound E	Pakistan	1355	16	157	141	37	157	55
293	15647	Mound E	Pakistan	1184	16	164	142	25	155	54
294	15648	Mound E	Pakistan	1081	14	179	103	42	168	55
295	15649	Mound E	Pakistan	1342	17	150	161	41	167	53

296	15650	Mound E	Pakistan	1325	18	160	112	27	179	54
297	15651	Mound E	Pakistan	1054	18	165	118	39	154	56
298	15653	Mound E	Pakistan	919	13	157	178	32	118	51
299	15654	Mound AB	Pakistan	971	18	167	103	38	161	53
300	15655	Mound E	Pakistan	714	16	156	91	40	146	52
301	15656	Mound E	Pakistan	780	10	127	149	32	124	51
302	15657	Mound AB	Pakistan	1374	15	151	124	42	174	54
303	15658	Mound AB	Pakistan	819	15	164	81	40	161	52
304	15659	Mound E	Pakistan	1399	13	175	90	32	166	55

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**APPENDIX C: A BASIC PETROGRAPHIC ANALYSIS OF CERMAICS FROM  
KUWAIT**

**By Mary F. Ownby**

This report was written by Dr. Mary F. Ownby, Desert Archaeology, Inc., in 2013 and was appeared in the PhD dissertation of Hasan Ashkanani appendix based on an agreement contract between Hasan Ashkanani and Mary F. Ownby. The purpose of this report is to conduct petrographic analysis of 25 thin sections and prepare a report (only grouping the samples and describing the slides). The report consists of 18 pages.



# **A Basic Petrographic Analysis of Ceramics from Kuwait**

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Mary F. Ownby

Submitted to  
Hasan Ashkanani  
1622 Brookfield Drive  
Ann Arbor, MI 48103



**Petrographic Report No. 2013-04**  
**Desert Archaeology, Inc.**

3975 N. Tucson Blvd., Tucson, AZ 85716 • September 2013

## TABLE OF CONTENTS

LIST OF TABLES .....	3
INTRODUCTION.....	4
METHODS.....	4
RESULTS.....	4
Group A .....	5
Group B.....	6
Outliers .....	7
CONCLUSION .....	7
APPENDIX A. THIN SECTION RECORDED DATA.....	8
REFERENCES CITED .....	18

## LIST OF TABLES

1. Sample inventory.....	5
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# A BASIC PETROGRAPHIC ANALYSIS OF CERAMICS FROM KUWAIT

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## INTRODUCTION

This basic report provides petrographic descriptions of 25 ceramic thin sections from Kuwait. The analyzed pottery derives from sites assigned to the Dilmun culture, which is known for its critical role in trade between Mesopotamia and the Indus Valley as well as intraregionally. The placement of the samples into petrographic groups should assist in determining those that are likely imports from local productions, or copies of imported forms. While provenance assignments are not within the scope of this basic study, technological information is provided.

## METHODS

Thin sections of the 25 ceramic samples were already prepared, with most appearing to have been produced from the cross-section of the vessel wall (Table 1). Analysis focused on recording standard petrographic information including color of the thin section in plane and cross-polarized light, and optical activity of the matrix (fired clay and inclusions) to provide general information on firing temperature, and the type of temper (Whitbread 1989; Ownby 2010). Other descriptors included the percentage of inclusions, their sorting, size range, and shape range, which was based on inclusions larger than silt-sized that in many cases are natural to the clay. Size range uses the Wentworth (1922) scale for sand so that: very fine = 0.0625-0.125mm, fine = 0.125-0.25 mm, medium = 0.25-0.5 mm, coarse = 0.5-1 mm, and very coarse = 1-2 mm. The individual mineral fragments were identified and when possible rock fragments were specified to general geological environment (i.e., volcanic, metamorphic, sedimentary). More specific identification was possibly only rarely as the rock fragments were mostly fine to medium in size. Information was noted on the clay and possible modifications to prepare it for pottery production. Identification of temper can be very difficult when the clays are naturally sandy. Mostly the bimodal nature of the inclusions and the roundedness of the larger grain sizes were utilized as an indicator of sand temper. Typically, when sand temper was present the percentage of inclusions was also higher, but a few samples had common fine-sized inclusions. Information on the process for forming the vessels, i.e. elongated voids suggestive of wheel throwing, was difficult to identify in part because some of the thin sections were small and/or overly thinned. For some samples, the latter issue also made identification of the clay and mineral inclusions challenging.

## RESULTS

During the petrographic analysis several distinct groups with similar clay and inclusions were identified (see Table 1). The discussion of the results will be by these groups, and include general information on raw materials and ceramic technology. The petrographic descriptions for each sample are in Appendix A.

Table 1. Sample Inventory.

Sample No.	Site	Tradition	Petrographic Group
13613	F6 Palace	Indus?	Outlier
13617	F6 Palace	Dilmun	Group A.1
13618	F6 Palace	Indus?	Group A.2
13620	F6 Palace	Indus?	Group A.2
13622	F6 Palace	Dilmun	Group A.3
13631	F3 - 2A	Dilmun	Group A.3
13634	F3 - 2A	Dilmun	Group A.3
13661	Barabr II	Mesopotamian ??	Outlier
13662	Barabr II	Dilmun	Group A.3
13664	Barabr II	Dilmun	Group A.1
13676	Barbar IIIARP	Dilmun	Group A.1
13679	Barbar IIIARP	Dilmun	Group A.3
13701	alkhidr	Dilmun	Group A.1
14231	alkhidr	gray-green Meso?	Group A.3
14235	alkhidr	dilmun?	Group A.3
14259	alkhidr	gray-green Meso?	Group A.1
14270	alkhidr	Eastern provenance	Outlier
14288	alkhidr	Dilmun	Group A.1
15128	Trecnh E	Dilmun	Group A.1
15154	F6 Meso H.	Mesopotamian	Group B
15156	F6 Meso H.	unknown/Meso	Group B
15158	F6 Meso H.	unknown/Meso	Group B
15166	F6 Meso H.	Mesopotamian	Group B
15167	F6 Meso H.	Mesopotamian	Outlier
13681	Qlat IIF	Dilmun	Group A.3

### Group A

The largest group contained 17 samples, but within these were notable subgroups. The first subgroup, labeled Group A.1, comprised 7 samples with an iron-rich silty and micaceous clay. Typically inclusions were quartz, plagioclase, muscovite, biotite, pyroxene, amphibole, iron oxides, and opaques. All of the samples were tempered with sand that included rounded grains of quartz, plagioclase, potassium feldspar, and quartzite, though some sand could lack one of the feldspars or quartzite. Rare inclusions were often garnet, epidote, and zoisite. Several samples had very fine to fine-sized volcanic and metamorphic rock fragments that were within the clay. Almost all of the samples had uncommon chert fragments and micritic limestone, although the later in some cases appeared to be related to the sand temper. The overall characteristics of the clay suggest its source is from a river draining volcanic, metamorphic, and possibly sedimentary rocks. The sand may relate to the disaggregation of arkose rocks, some of which have become slightly deformed and appear more like quartzite. This is also suggested by the weathered appearance of some of the grains, particular the feldspars. The firing temperatures of these samples ranged from 750°C to probably closer to 850°C for samples 13617 and 13701. No evidence for the process of vessel formation was noted in the thin sections.

Subgroup A.2, with two samples, contains the same clay but lacks sand temper. Sample 13620 was probably low fired, i.e. 750-800°C, while Sample 13618 was fired to higher

temperatures, possibly up to 850°C. No evidence for the method of vessel production was identified.

Subgroup A.3 comprises eight samples that, while containing the same sand temper as Group A.1, were produced from different clays. Three samples, 13622, 13634, and 13679 were made from iron-rich clays that appeared more likely to derive from eroding shale. Sample 13622 was micaceous but not silty, with unusual calcareous inclusions from medium to coarse in size. Sample 13634 lacked mica or silty quartz, while Sample 13679 had a few silty quartz and mica grains. The latter sample was clearly fired above 850°C and had a bloated appearance, although the vessel was incompletely oxidized, giving it a gray core. The other two samples were more likely fired between 750°C and 800°C. Sample 13681 had an iron-rich clay similar to that used for the Group A.1 and A.2 samples, but with a calcareous component as well. The firing temperature was likely around 800°C. While Sample 13662 also had a clay that was a mixture of iron-rich and calcareous, its appearance was slightly different although the firing temperature was likely the same. This sample may be related to Sample 13631 and Sample 14235 which have a slightly analogous clay and are nearly identical to each other except for firing temperatures. Sample 13631 may have been fired above 800°C, while Sample 14235 was likely below this temperature. Interestingly, Sample 13631 was supposedly wheel thrown, but evidence of this was lacking in the thin section. Finally, Sample 14231 had a mostly calcareous clay but with some silty inclusions that are similar to those in the other Group A samples. Its firing temperature was likely around 800°C. For all of these samples the provenance is probably similar, due to the utilization of analogous sand temper and the iron-rich components in the clay that are comparable. The clay differences may suggest different production areas within a larger region or the utilization of various resources for specific vessel forms and/or vessel function.

## Group B

The four samples in Group B share similar inclusions that are natural to the clay and comprise mostly quartz, plagioclase, muscovite, biotite, iron oxides, and opaques. Less common inclusions are pyroxene, amphibole, garnet, chert, quartzite, and micritic limestone. Notable for these samples is the presence of fine-sized volcanic rock fragments that, while weathered, appear to be mostly mafic to intermediate in composition. A few could be identified as likely basalt. However, the clays varied between the samples. Sample 15154 had a non-silty iron-rich and calcareous clay, Sample 15156 had a calcareous clay, Sample 15158 had a slightly silty calcareous and iron-rich clay, and Sample 15166 had a calcareous clay with a different appearance from Sample 15156. The firing temperatures were probably mostly around 800°C for the samples, with Sample 15156 probably slightly lower. The components in the clay suggest they are all likely from a similar production area that probably utilized various riverine sediments due to the mixed nature of the inclusions. This would be closer to volcanic rock outcrops than the Group A samples, and far from an area with metamorphic rock formations. The sedimentary component seems analogous, however.

## Outliers

Four samples were unique and represent outliers, although some could be related to the two main petrographic groups, and all lacked temper. Sample 13613 had an iron-rich clay with similar silty and micaceous inclusions to Group A, but notable volcanic rock fragments and an absence of chert, quartzite, and micritic limestone. Most of the rock fragments appear to be basalt and, along with the clay, which is likely riverine in origin, suggests the raw materials derived from near mafic volcanic outcrops. The firing temperature was probably around 800°C and it appeared that a red slip was on one surface. Sample 13661 was produced from a green calcareous clay with grains of quartz, potassium feldspar, plagioclase, pyroxene, amphibole, iron oxides, and opaques. The lack of mica and sedimentary inclusions suggests it is unlike the other samples and its clay is unique. Some of the pores were elongated, which may support the suggestion it was wheel-made, and the firing temperature probably exceeded 800°C. Sample 14270 may relate to the Group A samples with an iron-rich silty and micaceous clay, along with a calcareous component. However, it contains unusual inclusions that are clay-rich with minor silty inclusions such as quartz. These are suggested to be clay pellets based on their inclusions, shape, and size. The boundaries with the matrix are mostly indistinct suggesting they are less likely grog. The firing temperature was probably between 800°C and 850°C. Finally, Sample 15167 has a calcareous clay like Sample 15156 and a few similar volcanic rock fragments, but also has prominent metamorphic rock fragments that resemble schist. This suggests a source closer to low-grade metamorphic rocks but probably from riverine raw materials. The firing temperature was likely 750°C to 800°C.

## CONCLUSION

This petrographic analysis, though basic in its interpretations, has provided important information on the mineral and rock constituents and the clays utilized as raw materials. Except for Group A, for which most samples have sand temper, the vessel paste derived from untempered clays. These clays could be iron-rich or calcareous, or a mixture of both. The large variety of minerals and small rock fragments suggest riverine sediments were the preferred raw clay source, although a few samples such as Sample 13661 may have clay from primary clay beds eroding from in-situ rock formations. While a specific provenance for the petrographic groups and outliers is beyond the scope of this basic study, it remains likely that these Kuwaiti sites were involved in the movement of pottery from a number of different locations. This is not surprising as the Dilmun culture was ideally located for connecting the Indus Valley cultures with those in Mesopotamia and the Arabian Peninsula.

## APPENDIX A

### THIN SECTION DESCRIPTIONS



**Sample 13613**

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: slight

Temper Type: none

% of inclusions: 5%

Sorting: well sorted

Size Range: very fine to medium

Shape Range: angular to subrounded

Main inclusions: quartz, plagioclase, muscovite, biotite, pyroxene, amphibole, iron oxides, and opaques

Additional inclusions: volcanic rock fragments (mostly hypocrySTALLINE basalt), chert?, micritic limestone?

Comments: clay is iron-rich and silty/micaceous; all inclusions are natural; the firing temperature is likely to be around 800°C due to slightly active matrix.

**Sample 13617**

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: inactive

Temper Type: sand

% of inclusions: 20%

Sorting: good

Size Range: very fine to coarse

Shape Range: angular to well-rounded

Main inclusions: quartz, plagioclase, muscovite, biotite, pyroxene, amphibole, iron oxides, and opaques

Additional inclusions: potassium feldspar, garnet, chert, micritic limestone, potassium feldspar?, gneiss?

Comments: clay is iron-rich and silty/micaceous with added sand temper; sand temper comprises quartz, plagioclase, potassium feldspar, quartzite; firing temperature is likely between 800°C and 850°C due to optically inactive matrix.

**Sample 13618**

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: inactive

Temper Type: none

% of inclusions: 5%

Sorting: well sorted

Size Range: very fine to medium

Shape Range: angular to subrounded

Main inclusions: quartz, plagioclase, muscovite, biotite, pyroxene, amphibole, iron oxides, and opaques

Additional inclusions: garnet, chert, micritic limestone, zoisite, metamorphic rock fragment?, plant remains?

Comments: clay is iron-rich and silty/micaceous; all inclusions are natural to the clay; the firing temperature is likely to be around 850°C as matrix is not optically active.

**Sample 13620**

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: active

Temper Type: none

% of inclusions: 5%

Sorting: good

Size Range: very fine to medium

Shape Range: angular to subrounded

Main inclusions: quartz, plagioclase, muscovite, biotite, pyroxene, amphibole, iron oxides, and opaques

Additional inclusions: garnet, chalcedony, micritic limestone, zoisite, volcanic rock fragments, metamorphic rock fragments?, granite?, chert?, chlorite?

Comments: clay is iron-rich and silty/micaceous; all inclusions are natural to the clay; the firing temperature is likely to be around 750°C as matrix is optically active and limestone is mostly intact (i.e., not decomposed) but slide is thin in areas; probably a short firing leaving the core less red/oxidized.

**Sample 13622**

Color PPL: reddish tan

Color XPL: reddish tan

Optical Activity: active

Temper Type: sand

% of inclusions: 20%

Sorting: fair

Size Range: very fine to coarse

Shape Range: subangular to well-rounded

Main inclusions: quartz, biotite, muscovite, iron oxides, and opaques

Additional inclusions: plagioclase, potassium feldspar, quartzite, metamorphic rock fragments?

Comments: clay is iron-rich but non-silty being more micaceous (eroding shale?); sand temper comprises quartz, plagioclase, potassium feldspar, and quartzite; gray calcareous areas appear to be natural to the clay suggesting a natural mix between an iron-rich and calcareous deposit; the firing temperature is likely to be between 750°C and 800°C (optically active) but slide is thin.

**Sample 13631**

Color PPL: brownish gray

Color XPL: grayish brown

Optical Activity: inactive

Temper Type: sand

% of inclusions: 20%

Sorting: fair

Size Range: very fine to coarse

Shape Range: subangular to well-rounded

Main inclusions: quartz, plagioclase, biotite, muscovite, pyroxene, amphibole, iron oxides, and opaques

Additional inclusions: micritic limestone, potassium feldspar, chert, chalcedony, quartzite, metamorphic rock fragments?

Comments: calcareous and silty clay; sand temper comprises quartz, plagioclase, potassium feldspar, and quartzite; the firing temperature was likely around 800°C due to inactive matrix.

#### **Sample 13634**

Color PPL: reddish tan

Color XPL: reddish tan

Optical Activity: active

Temper Type: sand

% of inclusions: 20%

Sorting: fair

Size Range: very fine to coarse

Shape Range: subangular to well-rounded

Main inclusions: quartz, potassium feldspar, iron oxides, and opaques

Additional inclusions: micritic limestone, plagioclase, muscovite, biotite, pyroxene, quartzite

Comments: iron-rich and non-silty clay with common iron oxides and opaques (not like 13622); sand temper comprises quartz, potassium feldspar, and quartzite; clay could be from an eroding shale; firing temperature was likely around 750°C due to optically active matrix.

#### **Sample 13661**

Color PPL: yellowish gray

Color XPL: grayish yellow

Optical Activity: inactive

Temper Type: none

% of inclusions: 5%

Sorting: well sorted

Size Range: very fine to fine

Shape Range: very angular to subrounded

Main inclusions: quartz, iron oxides, and opaques

Additional inclusions: potassium feldspar, plagioclase, pyroxene, amphibole, rock fragments (too small to identify further), quartzite?, chert?, calcite?

Comments: calcareous clay with natural inclusions mostly of quartz, iron oxides, and opaques; matrix appears to indicate firing temperatures at least 850°C or higher.

#### **Sample 13662**

Color PPL: reddish gray

Color XPL: reddish gray

Optical Activity: slight

Temper Type: sand

% of inclusions: 10%

Sorting: fair

Size Range: very fine and coarse

Shape Range: subangular to well-rounded

Main inclusions: quartz, plagioclase, muscovite, biotite, amphibole, iron oxides, and opaques  
Additional inclusions: micritic limestone, potassium feldspar, chert, quartzite, rock fragments (too small to identify further), tourmaline?  
Comments: calcareous and iron-rich clay that is silty/micaceous; sand temper comprises quartz, plagioclase, and potassium feldspar; the firing temperature was likely around 800°C due to slight optical activity of the matrix.

**Sample 13664**

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: active

Temper Type: sand

% of inclusions: 10%

Sorting: fair

Size Range: very fine to coarse

Shape Range: angular to well-rounded

Main inclusions: quartz, plagioclase, muscovite, biotite, amphibole, iron oxides, and opaques

Additional inclusions: micritic limestone, potassium feldspar, chert, chalcedony, quartzite, pyroxene, metamorphic rock fragments, zoisite, olivine?, garnet?, tourmaline?

Comments: clay is iron-rich and silty/micaceous; sand temper comprises quartz, plagioclase, and potassium feldspar; the firing temperature was probably between 700°C and 800°C due to optical activity of the matrix (limestone is gone, but seems more a result of thin sectioning process); color difference due to shorter firing time.

**Sample 13676**

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: active

Temper Type: sand

% of inclusions: 30%

Sorting: fair

Size Range: very fine to very coarse

Shape Range: angular to well-rounded

Main inclusions: quartz, muscovite, biotite, amphibole, iron oxides, and opaques

Additional inclusions: plagioclase, potassium feldspar, pyroxene, micritic limestone, chalcedony, chert, quartzite, zoisite, epidote, volcanic and metamorphic rock fragments

Comments: clay is iron-rich and silty/micaceous; sand temper comprises quartz, plagioclase, potassium feldspar, and quartzite; firing temperature likely from 700°C and 800°C due to optical activity of the matrix; red slip on one surface.

**Sample 13679**

Color PPL: red with black core

Color XPL: red with black core

Optical Activity: inactive

Temper Type: sand

% of inclusions: 40%

Sorting: fair

Size Range: very fine to coarse

Shape Range: subangular to well-rounded

Main inclusions: quartz, potassium feldspar, plagioclase, chert

Additional inclusions: muscovite, biotite, amphibole, iron oxides, opaques, micritic limestone, quartzite, volcanic rock fragment?, garnet?

Comments: iron rich clay that has been overfired and appears bloated; sand temper comprises quartz, plagioclase, potassium feldspar, and quartzite; firing temperature probably exceeded 850°C but perhaps only briefly due to unoxidized grey core.

#### **Sample 13701**

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: slight

Temper Type: sand

% of inclusions: 20%

Sorting: fair

Size Range: very fine to coarse

Shape Range: subangular to well-rounded

Main inclusions: micritic limestone, quartz, plagioclase, potassium feldspar, muscovite, biotite, iron oxides, and opaques

Additional inclusions: chert, chalcedony, pyroxene, amphibole, quartzite, epidote, zoisite, garnet, titanite, and volcanic and metamorphic rock fragments

Comments: clay is iron-rich and silty/micaceous; sand comprises quartz, plagioclase, potassium feldspar, and quartzite; one surface appears to have a calcareous slip that may overlie an iron-rich slip but both are inconsistent; firing temperature was probably between 800°C and 850°C due to reduced optical activity and possibly decomposed limestone.

#### **Sample 14231**

Color PPL: brownish gray

Color XPL: grayish brown

Optical Activity: slight

Temper Type: sand

% of inclusions: 10%

Sorting: fair

Size Range: very fine to medium

Shape Range: subangular to well-rounded

Main inclusions: quartz, muscovite, biotite, iron oxides, opaques, and micritic limestone

Additional inclusions: plagioclase, potassium feldspar, chert, quartzite, amphibole, metamorphic rock fragments?

Comments: calcareous and silty/micaceous clay; sand temper comprises quartz, potassium feldspar, and quartzite; the firing temperature was likely around 800°C due to optically inactive matrix.

#### **Sample 14235**

Color PPL: brownish gray

Color XPL: grayish brown

Optical Activity: slight

Temper Type: sand

% of inclusions: 10%

Sorting: fair

Size Range: very fine to medium

Shape Range: subrounded to well-rounded

Main inclusions: quartz, muscovite, biotite, iron oxides, opaques, and micritic limestone

Additional inclusions: plagioclase, potassium feldspar, chert, quartzite, amphibole, pyroxene, epidote, zoisite, volcanic rock fragment, sparry limestone, metamorphic rock fragments?, tourmaline?, garnet?

Comments: calcareous and silty clay; sand temper comprises quartz, potassium feldspar, plagioclase, and quartzite; firing temperature was probably between 750°C and 800°C due to intact limestone and slight optical activity.

#### Sample 14259

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: active

Temper Type: sand

% of inclusions: 10%

Sorting: fair

Size Range: very fine to coarse

Shape Range: subangular to well-rounded

Main inclusions: quartz, plagioclase, muscovite, biotite, amphibole, iron oxides, and opaques

Additional inclusions: micritic and sparry limestone, potassium feldspar, pyroxene, garnet, epidote, zoisite, chert, quartzite, metamorphic and volcanic rock fragments, olivine?, tourmaline?

Comments: clay is iron-rich and silty/micaceous; sand temper comprises quartz, potassium feldspar, plagioclase, and quartzite; firing temperature was probably closer 750°C due to intact limestone and optical activity

#### Sample 14270

Color PPL: grayish red

Color XPL: grayish red

Optical Activity: slight

Temper Type: none

% of inclusions: 5%

Sorting: well sorted

Size Range: very fine to medium

Shape Range: angular to subrounded

Main inclusions: quartz, plagioclase, muscovite, biotite, pyroxene, amphibole, iron oxides, and opaques

Additional inclusions: potassium feldspar, micritic limestone, quartzite, garnet, volcanic rock fragments, other rock fragments (too small to identify), likely clay pellets, chert?

Comments: clay is iron-rich and silty/micaceous with a calcareous component; all inclusions are natural; unusual iron-rich inclusions are likely clay pellets; the firing temperature is likely to be around 800°C.

**Sample 14288**

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: active

Temper Type: sand

% of inclusions: 20%

Sorting: fair

Size Range: very fine to coarse

Shape Range: subangular to well-rounded

Main inclusions: quartz, plagioclase, muscovite, biotite, amphibole, iron oxides, and opaques

Additional inclusions: potassium feldspar, pyroxene, micritic limestone, chert, chalcedony, quartzite, zoisite?, epidote?

Comments: clay is iron-rich and silty/micaceous; sand temper comprises quartz, potassium feldspar, and quartzite; firing temperature was probably between 750°C and 800°C due to intact limestone and optical activity (**thick thin section caused difficulties in analysis of this sample**).

**Sample 15128**

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: active

Temper Type: sand

% of inclusions: 20%

Sorting: fair

Size Range: very fine to coarse

Shape Range: subangular to well-rounded

Main inclusions: quartz, plagioclase, muscovite, biotite, iron oxides, and opaques

Additional inclusions: potassium feldspar, micritic limestone, chert, amphibole, pyroxene, epidote, quartzite, zoisite?, rock fragments?

Comments: clay is iron-rich and silty/micaceous; sand temper comprises quartz, plagioclase, potassium feldspar, and quartzite; firing temperature was probably around 800°C due optical activity.

**Sample 15154**

Color PPL: reddish gray

Color XPL: reddish gray

Optical Activity: inactive

Temper Type: none

% of inclusions: 10%

Sorting: well-sorted

Size Range: very fine to fine

Shape Range: angular to subrounded

Main inclusions: quartz, plagioclase, muscovite, biotite, iron oxides, and opaques

Additional inclusions: micritic limestone, chert, quartzite, amphibole, pyroxene, garnet, volcanic rock fragments (various textures and most likely mafic), olivine?

Comments: iron-rich and calcareous clay with some micaceous natural inclusions; volcanic

rock fragments are notable; firing temperature may have been around 800°C, but **this section was too thin to be positive and this also caused difficulties with the overall analysis.**

**Sample 15156**

Color PPL: tan

Color XPL: tan

Optical Activity: active

Temper Type: none

% of inclusions: 10%

Sorting: good

Size Range: very fine to medium

Shape Range: angular to subrounded

Main inclusions: quartz, plagioclase, muscovite, biotite, iron oxides, and opaques

Additional inclusions: micritic limestone, chert, quartzite, amphibole, pyroxene, garnet, epidote, zoisite, volcanic rock fragments (various textures and most likely mafic), serpentine?

Comments: calcareous clay with some iron-rich components and natural inclusions including mica; volcanic rock fragments are notable and are similar to 15154; firing temperature may have been around 800°C, but **this section was too thin to be positive and this also caused difficulties with the overall analysis.**

**Sample 15158**

Color PPL: reddish brown

Color XPL: reddish brown

Optical Activity: slight

Temper Type: none

% of inclusions: 10%

Sorting: good

Size Range: very fine to medium

Shape Range: angular to subrounded

Main inclusions: quartz, plagioclase, muscovite, biotite, iron oxides, and opaques

Additional inclusions: micritic limestone, chert, quartzite, amphibole, pyroxene, volcanic rock fragments (various textures and most likely mafic and intermediate), garnet, serpentine?, sphene?

Comments: iron-rich clay with natural inclusions including mica; volcanic rock fragments are notable and are similar to 15154; firing temperature probably around 800°C due to optical activity.

**Sample 15166**

Color PPL: gray

Color XPL: gray

Optical Activity: inactive

Temper Type: none

% of inclusions: 20%

Sorting: good

Size Range: very fine to fine

Shape Range: angular to subrounded



Main inclusions: quartz, plagioclase, muscovite, biotite, iron oxides, and opaques  
Additional inclusions: chert, quartzite, amphibole, pyroxene, volcanic rock fragments (various textures and most likely mafic and intermediate)  
Comments: mostly calcareous clay but likely with a small iron-rich component, slightly micaceous; volcanic rock fragments are notable and are similar to 15158; firing temperature was probably between 800°C and 850°C due to optical inactivity, but **this section was too thin to be positive and this also caused difficulties with the overall analysis.**

**Sample 15167**

Color PPL: tan

Color XPL: tan

Optical Activity: active

Temper Type: none

% of inclusions: 20%

Sorting: good

Size Range: very fine to fine

Shape Range: angular to subrounded

Main inclusions: quartz, plagioclase, muscovite, biotite, amphibole, iron oxides, and opaques

Additional inclusions: chert, quartzite, calcite, micritic and sparry limestone, pyroxene, potassium feldspar, zoisite, metamorphic rock fragments (some are likely schist), volcanic rock fragments (various textures and most likely mafic and intermediate), serpentine?

Comments: calcareous and iron-rich/micaceous clay with natural inclusions; volcanic rock fragments are notable and are similar to 15156, but there are definite metamorphic rock fragments as seen in a few other samples; firing temperature was likely between 750°C and 800°C due to optical activity and intact calcareous material.

**Sample 13681**

Color PPL: reddish tan

Color XPL: reddish tan

Optical Activity: slight

Temper Type: sand

% of inclusions: 20%

Sorting: fair

Size Range: very fine to medium

Shape Range: subangular to well-rounded

Main inclusions: quartz, plagioclase, muscovite, biotite, iron oxides, and opaques

Additional inclusions: chert, sparry and micritic limestone, calcite, pyroxene, amphibole, potassium feldspar, microfossils, zoisite, epidote, serpentine?

Comments: iron-rich silty/micaceous and calcareous clay; sand temper comprises quartz, potassium feldspar, and quartzite; firing temperature was probably between 750°C and 800°C due to intact limestone and optical activity (if microfossil is from a gastropod, indicates riverine origin for raw materials).

## REFERENCES CITED

Ownby, Mary F.

- 2010 Canaanite Jars from Memphis as Evidence for Trade and Political Relationships in the Middle Bronze Age. Unpublished Ph.D. Thesis, University of Cambridge.

Wentworth, Chester K.

- 1922 A Scale of Grade and Class Terms for Clastic Sediments. *Journal of Geology* 30:377-392.

Whitbread, Ian

- 1989 A Proposal for the Systematic Description of Thin Sections towards the Study of Ancient Ceramic Technology. In *Archaeometry: Proceedings of the 25th International Symposium*, edited by Y. Maniatis, pp. 127-138. Elsevier, New York.

## APPENDIX D: PERMISSIONS

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### Figure 2.4 (Højlund 1994:76)

**From:** Flemming Højlund [<mailto:flemming.hoejlund@moesmus.dk>]  
**Sent:** Monday, April 14, 2014 2:41 AM  
**To:** Anne Lise Hansen; Burke, Marilyn; [ahj@unipress.au.dk](mailto:ahj@unipress.au.dk)  
**Subject:** SV: use of an image

Dear Marilyn,  
Permission granted with pleasure.  
Best wishes, Flemming Højlund

---

**Fra:** Burke, Marilyn [<mailto:msburke@usf.edu>]  
**Sendt:** 2. april 2014 20:16  
**Til:** 'unipress@au.dk'  
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Thank you for your time

All the best,

Hasan

<dales and kenoyer 1991\_2.png><dales and kenoyer 1991\_1.png>

Hasan Ashkanani  
Ph.D. program  
Department of Anthropology

Figure 7.18 (Ashkanani and Tykot 2013)

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308